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TROUBLESHOOTING ELECTRONIC EQUIPMENT

TROUBLESHOOTING PRINCIPLES

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TROUBLESHOOTING ELECTRONIC EQUIPMENT

U. S. BUREAU OF NAVAL PERSONNEL

FOREWORD

This text was developed by the Chief of Naval Personnel for use in schools that provide instruction in troubleshooting electronic equipment.

Since it is written in a programed-learning format, the text can also be used by individuals or groups in ships or activities where no formal training is conducted.

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Captain, U.S. Navy
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PREFACE

This book has been prepared for Navy personnel whose rating requires a troubleshooting capability in electronic equipment. It describes the method used by competent and experienced technicians to isolate an equipment malfunction in a rapid, systematic manner. The text can provide the reader with the principles of troubleshooting, and synthetic problems are included that parallel their application on actual equipment. However, competent skill can only be attained through continued experience in applying these principles each time the technician troubleshoots a malfunctioning equipment.

Although primarily intended for those who are receiving their initial training in electronic skills, the text can also be used effectively by those in the fleet who are having difficulties in troubleshooting. The book was prepared in a programed-learning format to enhance its self-study features.

NavPers 93083, Troubleshooting Electronic Equipment consists of three volumes as follows:

NavPers 93083A-1	Troubleshooting principles
NavPers 93083A-2	Test Equipment problems (oscilloscope)
NavPers 93083A-3	Technical Manual for Oscilloscope, TS-O

This series supersedes NavPers 93083, Volume I, Part 1 and 2, and Volume II

When ordering this publication request NavPers 93083A-1, 93083A-2, and 93083A-3.

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INTRODUCTION

The purpose of this self-instruction course is to provide you with an introduction to, and practice in, the basic concepts of troubleshooting principles. It is realized that the average individual who will take this course is a newcomer to the vast and interesting field of electronics.

The functioning of any shore or shipboard naval installation is almost entirely dependent upon the proper continuous operation of many different types of electronic equipments. This requirement clearly supports the fact that the primary job of the electronics technician, aside from normal military duties, is the maintenance of these equipments.

The term "maintenance" refers to all actions which a person performs on an actual piece of equipment or machinery to retain the equipment in a serviceable condition or to restore it to serviceability. This involves inspection, testing, servicing, repair, rebuilding, etc. Proper maintenance of equipment cannot be performed by an untrained person, but must be performed by a person who is thoroughly familiar with the equipment. This familiarity requires a knowledge of how the equipment performs its task - the "theory of operation".

A logical or systematic approach to troubleshooting is paramount in a technician's over-all knowledge of electronics. Many man-hours have been lost because of the time consuming "hit-or-miss" methods of trouble analysis.

The trouble analysis procedure presented in this text has been developed to give you a path to follow toward the ultimate goal of effective equipment maintenance and optimum operational capability. If you can grasp the concept and basic importance of the suggested troubleshooting steps explained in the following pages, you will gain the ability to troubleshoot any electronic equipment regardless of its complexity or purpose.

The teaching method employed by this book is based upon a relatively new formula for the writing and presentation of subject matter. This concept has evolved from the recent advances made in using automated teaching methods to allow individuals an opportunity to gain an education without being physically present in an instructor guided class session.

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The material is presented in such a manner that it closely parallels the words spoken by an instructor in an actual classroom. Subjects are introduced and discussed in relatively small units of subject matter organized in such a logical sequence that learning can take place with minimual help. Study each block of information carefully. As each information block is completed, a question is asked to immediately check your understanding of the subject matter contained in the information block. A group of selections are provided. Make every effort to choose the correct one prior to continuing your study. If necessary, restudy the information block. Immediate reinforcement is provided by placing the answers to each selection frame in a following left-hand page. An incorrect choice will result in a further discussion of the subject, providing additional information which will aid you in understanding the material. A correct selection includes a discussion of why the answer is correct. If, after selecting the correct choice, you wonder why the other selections were incorrect, be sure to read the information provided under the incorrect selections. A new block of information follows the answers.

The benefits of learning which can be obtained from this type of textbook are primarily dependent upon your interest in learning the subject, attentiveness to following directions, and an open mind. With this throught impressed on our memory, let us direct our thinking toward developing an analytical method for troubleshooting electronic equipments.

LESSON NO. 1

INTRODUCTION TO TROUBLESHOOTING ANALYSIS

THE TECHNICIAN AND TROUBLESHOOTING

Your responsibilities as a Naval technician are those of any rating classification. You have two general areas of responsibilities -- military and technical. It is the technical phase of the responsibility which we are mostly interested in at this time.

As a result of the tremendous expansion of the electronics industry to meet the needs of World War II and the postwar demand for more powerful and accurate instruments of destruction and detection, there exists today a great number of electronic equipments. All of these require preventive and corrective maintenance to keep them in continuous operation. Troubleshooting, along with all of its necessary tests, is the most important part of this maintenance.

"Troubleshooting" is a term we in the electronics field hear continually. But, what does it mean? Troubleshooting is sometimes misinterpreted to mean simply fixing an equipment when it fails. This is only part of the "big" picture. In addition, the troubleshooter must be able to evaluate equipment performance by comparing his theoretical knowledge with the present indications of performance characteristics. This evaluation must be made both before and after repairs are accomplished for reasons which will become apparent as you progress through this book.

Performance data, along with other general information for various electronic equipments, are available to aid you in making an intelligent comparison of the operation characteristics of specific Navy equipment. The information provided in these performance testing books will give you a step-by-step performance check with all test connections and test equipment clearly indicated for each step. These publications are to serve as aids--not crutches--in helping you to become a skilled troubleshooter.

QUESTIONS:

A. Why is there such a great demand for qualified technicians?

B. Does the term "troubleshooting" imply that the technician need only locate the trouble but not necessarily make the repair?

C. How can performance records help the technician?

A. Why is there such a great demand for qualified technicians?

The pace of training new technicians has not kept up with the new equipment being developed. Demands are for the technician to maintain more and more complex pieces of electronic equipment. Such demands can only be met by training personnel to approach all maintenance problems in a logical manner.

B. Does the term "troubleshooting" imply that the technician need only locate the trouble but not necessarily make the repair?

Troubleshooting means realizing there is a trouble, diagnosing and locating the faulty functional unit, and making the necessary adjustments or repairs to restore the equipment to normal operation. The technician must be alert in order to determine if more than one failure exists in the equipment.

C. How can performance records help the technician?

Performance records are made when the equipment is operating normally. By comparing the equipment's present operation (meter readings, dial settings, etc.) with the performance records, the technician can determine if his equipment operation is deteriorating.

WHY BE LOGICAL?

Before entering into a discussion of the details of the primary subject matter--troubleshooting analysis--it is necessary to establish the basic element upon which satisfactory trouble analysis is based. This basic element, so very often overlooked in almost every endeavor, is a logical approach. According to up-to-date terminology, the definition of logic is: "the system or principles of reasoning applicable to any branch of knowledge or study." Examining the definition and its relation to our subject, it would be well to underline the words principles of reasoning. In a broad sense, reasoning is, in itself, logic.

When one examines the complex nature of most of today's electronic systems, whether military or commercial, it should be apparent that the personnel who are assigned to keeping the equipment operational must have specific training. These electronic technicians are far from superhuman beings in understanding and maintaining such devices. So what is the secret of their capability? It is simply and basically the fact that they have learned to think logically.

When you have assimilated the fundamental theories related to basic electronic circuitry, you will be well prepared to learn how they may be combined to form a complete system designed to do a specific task. Armed with this knowledge and a logical approach, you can functionally divide any electronic (or for that matter, nonelectronic) equipment and test it in an orderly and professional fashion. This procedure will save you valuable man-hours which are completely wasted when a haphazard technique is employed.

A logical or systematic approach is a fundamental concept that each and every step of the troubleshooting technique explained in this text has as its underlying thought.

Which of the selections below tells why it is necessary to have a logical general procedure for performing troubleshooting projects?

SELECTIONS:

A. The Navy's equipment is too complex to troubleshoot without a logical procedure.

B. With such a procedure I can troubleshoot any electronic equipment regardless of its simplicity or complexity.

C. A logical approach is applicable to the simplified equipment, but another approach must be employed with more complex equipment.

A. The Navy's equipment is too complex to troubleshoot without a logical procedure.

No. The Navy has simple electronic gear as well as complex equipment. You job will be to keep all of it in tip-top operating condition. Adopting a single, logical troubleshooting procedure will save you a lot of time and mistakes, as well as enabling you to repair any type of electronic equipment with a minimum of outside help.

B. With such a procedure, I can troubleshoot any electronic equipment regardless of its simplicity or complexity.

You are correct. The Navy has electronic equipments of all types. Your job will be to keep all of them in tip-top operating condition, and a single, logical troubleshooting procedure will permit you to accomplish this responsibility with confidence and efficiency. So far, the questions have been easy to answer--primarily so that you could get accustomed to the Automated Text principle. But be on your toes--the rest of the book contains more difficult questions which will require careful study of the information presented and a lot more thought.

C. A logical approach is applicable to the simplified equipment, but another approach must be employed with more complex equipment.

No. The logical approach presents a step-by-step approach to troubleshooting and is applicable to all electronic equipment maintained by the technician. If each step is "thought out" before proceeding to the next step, the technician will develop a systematic procedure toward troubleshooting.

THE SIX-STEP PROCEDURE

At this point, it should be apparent that a standardized approach toward electronic equipment troubleshooting and maintenance procedures will ultimately save many hours of needless equipment "down time" and costly repairs caused by improper maintenance techniques. Another equally important point is to keep electronic equipment in a constant state of operational readiness equivalent to the design standards specified by the equipment manufacturer.

All of the above will be within your capabilities if you learn and adopt the six-step trouble analysis procedure taught by this book. The following is a brief description of these six steps.

Symptom Recognition

This is the first step in our logical approach to trouble analysis. In order to repair an equipment you must first determine whether it is functioning correctly or incorrectly. To completely satisfy this step, you must be thoroughly familiar with the operational characteristics of the equipment in question. This means that you can provide valid answers to the questions--"what is this equipment supposed to do?" and "how well is this job being done?" Symptom recognition, then, is the determination of abnormal performance.

Symptom Elaboration

As a second step, the obvious or not so obvious symptom should be further defined. Most all electronic devices or systems have operational controls, additional indicating instruments other than the main indicating device, or other built-in aids for evaluating performance. These should be utilized at this point to see whether they will affect the symptom under observation or provide additional data that further defines the symptom. This step is the "I need more information" step in our systematic approach.

In view of the previous discussion outlining the first two steps, what action should the technician take when a trouble is reported to him?

SELECTIONS:

A. Observe the symptom, remove the side panels and make voltage checks.

B. Observe the symptoms and operate the controls of the equipment.

C. Shut off the power and take ohmmeter readings of the suspected circuit.

A. Observe the symptoms, remove the side panels and make voltage checks.

What circuit would you choose to make the first checks? Considerable time would be wasted in trying to locate a faulty circuit in this manner. You must first determine that there is a faulty circuit. Quite often a trouble symptom in electronic equipment is caused by some misadjustment of operating controls.

B. Observe the symptoms and operate the controls of the equipment.

Right again. The first two steps are very important in establishing the trouble. A considerable amount of time could be wasted if the technician failed to evaluate the reported trouble.

C. Shut off the power and take ohmmeter readings of the suspected circuit.

To determine what circuits should be checked, the technician must first determine that there actually is a faulty circuit. Trouble symptoms can be caused by misadjusted controls, faulty circuits or loss of power.

Listing of Probable Faulty Functions

The third step is an "estimation step" which makes maximum use of information from two sources: (1) the information gathered about the trouble symptom from steps 1 and 2 and (2) your knowledge of the functional units of the equipment. The term "faulty function" is really an educated estimate of the area in which the trouble might be located in order to cause the indicated symptoms. Several technically accurate possibilities may be considered as the probable trouble location area.

The term, function, is used here to denote an electronic operation performed by a specific area of an equipment; for example, functions may be entitled transmitter, receiver, power supply, or modulator. These functions, combined together, make up an equipment set (radar set, transceiver set, sonar set, etc.) and cause the set to perform the electronic purpose for which it was designed. Frequently, the terms, "function" (an operational sub-division of a set) and "unit" (a physical sub-division) are synonomous. However, there are occasions when one or more circuits for a particular function may be physically located in other than the indicated unit.

Localizing the Faulty Function

The fourth step involves choosing one of the faulty function selections for further examination. The selection chosen to be checked first should be based upon your understanding of equipment operation, ease of making the required test, and possible elimination of one or more educated guesses by performing this test. You will apply your understanding of the proper use of test equipment.

Most all electronic equipments can be practically sub-divided into units or areas which have a definite purpose or function. You may isolate the faulty function with your first test. If not, the information gained from the test can be applied toward deciding the next faulty function selection(s) to check. It may also lead to the development of other faulty function selections.

From the short explanation given on the third and fourth trouble-shooting steps, which of the following best describe the action of the technician in performing these steps?

SELECTIONS:

A. Prepare a list of probable trouble areas then utilize test equipment to isolate the faulty function.

B. Adjust the controls and choose the most likely function to begin making tests.

C. Prepare a list of probable troubles and utilize test equipment to make checks in the order that the troubles are listed.

A. Prepare a list of probable trouble areas, then utilize test equipment to isolate the faulty function.

You are following the logical approach exactly. The first four steps deal mainly with using your senses and test equipment to localize the trouble to a particular function. Remember that some tests may be easy to make and can thus be eliminated almost immediately. Information received during these checks will be valuable in determining where future checks should be made.

B. Adjust the controls and choose the most likely function to begin making tests.

Adjusting the controls was covered in step two, not steps three and four. Each step is equally important and must be practiced in sequence if the correct troubleshooting procedure is to be developed. There may be a number of functions that could cause the trouble symptoms. A list of all these should be prepared so that none will be overlooked.

C. Prepare a list of probable troubles and utilize test equipment to make checks in the order that the troubles are listed.

Careful reading of the steps will ensure that you do not develop the wrong impression. Some tests are much easier made than others. This should be considered when making your first checks. It is quite possible that testing the third or fourth function listed may be made easily and would probably be made first.

Localizing Trouble to the Circuit

Just as it was necessary to localize the trouble to a specific function of the over-all equipment in the preceding step, it will now be necessary to isolate or localize the trouble to a specific circuit or circuit group within the function.

The educated guess approach is again used to determine which circuit or circuit group is defective. By making valid educated guesses and properly employing the signal-tracing procedures which will be discussed later in this book, you can systematically isolate the faulty circuit.

Failure Analysis

The sixth and final step in systematic trouble analysis is twofold in nature. It includes (1) isolation of the bad or improperly adjusted circuit component(s) and (2) verification of the troubleshooting findings. Isolation of the defective circuit component again requires the application of the educated guess as influenced by knowledge of the theory of circuit operation.

Prior to the replacement of the suspected component you should stop and analyze the entire sequence of indications and measurements to verify that the selected component could produce the symptoms and variations observed by you throughout the procedure. This final mental verification will enable you to determine whether some other malfunction may have caused the faulty component to go bad or whether the component selected is the sole cause of the equipment trouble. This completes the logical sequence of action required for trouble analysis.

When component isolation and verification of the findings have been made, you can perform prescribed repair procedures in replacing the faulty part.

Now that you have studied the six troubleshooting steps, select the group of factors below which most nearly constitutes the basis for the entire troubleshooting concept.

SELECTIONS:

A. Logical approach, equipment knowledge, interpretation of test data, and use of the information gained in each step.

B. Logical approach, equipment knowledge, interpretation of test data, and proficiency in circuit repair techniques.

C. Equipment knowledge, remembering past equipment failures, interpretation of test data, and memorizing equipment test point locations.

A. Logical approach, equipment knowledge, interpretation of test data, and use of the information gained in each step.

You made the correct choice of the factors which are most important. Although proficiency in circuit repair techniques is important in the over-all maintenance procedures, it has no place in developing a systematic analysis procedure. Remembering past equipment failures and memorizing equipment test point locations for all the equipment within your responsibility would be an impossible task. Besides, past troubles do not necessarily repeat themselves, and instruction books containing circuit diagrams are printed so that you won't have to memorize test points, as well as to give you general test procedures and operating characteristics.

B. Logical approach, equipment knowledge, interpretation of test data, and proficiency in circuit repair techniques.

The fourth factor in the above selection is important from the viewpoint of over-all maintenance practices, but it really has no place in the development of a systematic approach to trouble analysis.

The six-steps to troubleshooting electronic equipment are:

Step 1. Symptom Recognition
Step 2. Symptom Elaboration
Step 3. Listing of Probable Faulty Functions
Step 4. Localizing the Faulty Function
Step 5. Localizing the Trouble to the Circuit
Step 6. Failure Analysis

C. Equipment knowledge, remembering past equipment failures, interpretation of test data and memorizing equipment point locations.

No. There are two factors in your selection which do not have any bearing upon the six-step trouble analysis procedure. It is true that recalling past equipment failures may be helpful, but you should not rely upon the possibility that the same trouble will be the cause of a given symptom in every case. In electronic equipments, there are many possible troubles which can give about the same symptom indications. Don't be fooled. Think and much time can be saved. The other factor - memorizing equipment test point locations - is way off. You should never rely upon your memory in approaching any trouble analysis problem.

RELATIONSHIP BETWEEN STEPS

Now that you have an over-all idea of what the six-step logical troubleshooting procedure is and what each step is supposed to do, let us make

sure we understand how the steps fit together by constructing a block diagram.

Figure 2 fold-out page 1 located in the back of this book presents a block analysis of the six-step procedure along with the specific things you must do or use to satisfactorily complete the requirements of each step. It can be easily seen that Symptom Recognition requires the use of the eyes, ears, and previous knowledge. The terms eyes and ears are self-explanatory; the term knowledge refers to your understanding of the correct indications the equipment must provide when it is performing normally. Symptom Recognition presupposes the ability to recognize improper indications. Symptom Elaboration includes all the requirements of step 1 and, in addition, the manipulation of operational controls and recording (note taking) of the effect they have on the symptom. Listing of Probable Faulty Functions depends upon steps 1 and 2 plus using the equipment diagrams and stopping to think, "what functional area could cause the indicated symptoms?" Localizing the faulty function adds one more requirement--the proper use and understanding of the readings presented by testing devices. Localizing trouble to the circuit uses all the steps up to this point in further isolating the trouble area. Failure Analysis is the final step. Here the findings are reviewed and verified to assure that the suspected component is the core of the failure. Included in step 6, but actually not a part of the trouble analysis, is the repair and re-checking of the equipment to ensure that it is again operational.

One aspect in trouble analysis which is not shown on the block diagram of figure 2 fold-out page 1 is the possibility of a return path between blocks. This return path would result from a fault in thinking or in making tests on the equipment. For example, if you were well into step 5 in testing a suspected circuit and found nothing wrong, you should take a return path and find where you may have been led astray.

Referring to the six-step procedure outlined in figure 2, fold-out page 1, and its related discussion, which step would you say is the most important?

SELECTIONS:

A. Step 2.

B. All the steps are equally important.

C. Step 6.

A. Step 2

Good grief!!! You have missed the point completely. In any logical approach (which we feel the six-step procedure is) each step is as important as the next. One area may be more detailed than the next but holds equal importance in the over-all scheme.

B. All the steps are equally important

You are absolutely correct. It cannot be said too often that, in a logical procedure, each and every step bears equal importance. Up to this point in our study, the main thought has been the establishment of the fact that a systematic approach is mandatory in any efficient and successful trouble analysis as applied to electronic equipments. Knowledge of equipment operating characteristics is equally important.

C. Step 6

No. Step 6 does utilize all of the previous information provided, but it is just as important to recognize the symptom as to analyze it. Each step depends upon the information derived from the previous steps.

NOTE

All fold-out sheets should be returned to their normal position after a block of information, in which they are utilized, is completed.

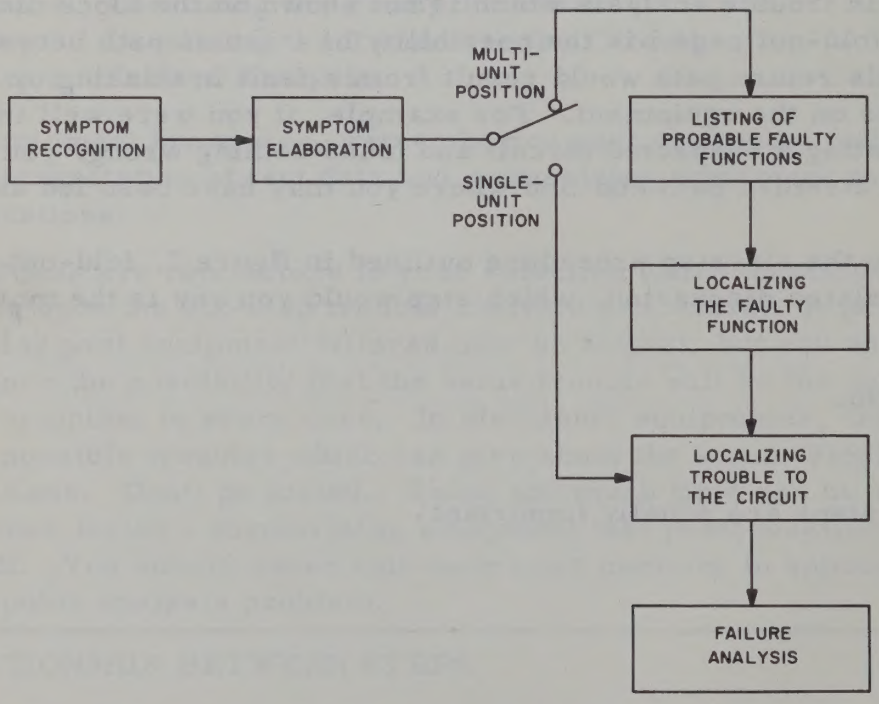

Figure 3. Modification of Six-Step Trouble-Shooting Procedure

OMISSION OF STEPS

Since step 3--Listing of Probable Faulty Functions--requires that the equipment be composed of more than one functional unit, this step may be omitted when the equipment consists of a single functional unit. This omission, in turn, would also allow you to omit step 4--localizing the faulty function. Thus, in the case of single-unit equipment, you can proceed directly from step 2 to step 5.

The single-unit equipment may be simple, such as a multimeter or a power supply. However, most single-unit equipments will be complex in nature.

Single-unit equipments provide a single function, i.e., AM-FM receivers provide reception; broadcast transmitters provide a means of transmitting a signal. Multi-unit equipments, such as radar or a transceiver, perform more than one function, i.e., transmission and reception.

Figure 3 shows the alternatives you are faced with after completing step 2--symptom elaboration. If the equipment contains more than one unit, you have no choice--you must include all six steps in our troubleshooting procedure. If there is only one functional unit, you may proceed directly from step 2 to step 5--omitting steps 3 and 4. The procedure will be fully described when the individual steps are discussed in detail.

In view of the above discussion, what factor(s) governs the exact troubleshooting procedure you must follow?

SELECTIONS:

A. Equipment design.

B. The length of time allowed for the troubleshooting project.

C. The nature of the trouble symptom.

A. Equipment design

Yes. If the equipment is complex enough to contain several functional units, you must follow the six steps--there is no choice in the matter. For single-unit equipment you may omit steps 3 and 4.

B. The length of time allowed for the troubleshooting project.

No! By omitting steps for such a reason you may ultimately need more time to complete the project than normally needed. This would be caused by an illogical procedure.

In the previous block of information you learned that each step is important. Omitting any step may result in an erronous conclusion and result in a waste of time utilizing test equipment to check a circuit when all the time the faulty symptom was due to faulty tunning.

C. The nature of the trouble symptom.

Absolutely not. The procedure you must use is a general procedure and is not dependent upon operational characteristics or symptoms of abnormal operation.

The six steps to troubleshooting electronic equipment is applicable to all troubles, simple or complex. Whether all six steps are necessary or not depends on what function the equipment performs.

It has been the intention of this first lesson to introduce you to the use of our automated text and to the six-step troubleshooting procedure.

1. Symptom Recognition
2. Symptom Elaboration
3. Listing of Probable Faulty Functions
4. Localizing the Faulty Function
5. Localizing Trouble to the Circuit
6. Failure Analysis

Possible omissions for the procedure have also been pointed out. A systematic, logical approach has been stressed throughout.

Now we are ready to begin a detailed study of the specific points which must be accomplished within each troubleshooting step.

STEP 1. SYMPTOM RECOGNITION

All electronic equipments are designed to do a specific job or group of jobs according to the requirements established by the Navy and the equipment manufacturer. This demands that a certain type of performance be obtainable at all times. If it were impossible to know when the equipment is performing poorly, it would be equally impossible to maintain the equipment in tip-top shape. For this reason the recognition of trouble symptoms is the first step in troubleshooting an equipment

A trouble symptom is a sign or indicator of some disorder or malfunction in an electronic equipment. Symptom recognition is the act of identifying such a sign when it appears.

When you have a fever or a headache, you know that there is a disorder somewhere in your body. When you hear a loud "knocking" sound in the engine of your care, you know that some part of the engine is not performing properly. Similarly, when you observe that the sound from a receiver is distorted, you know that there is a fault somewhere in the receiver or its supporting equipment.

Which of the following best describes "symptom recognition?"

SELECTIONS:

A. Symptom recognition is the distorted sound from a receiver.

B. Symptom recognition occurs when I become aware of some undesirable change in equipment performance.

C. Symptom recognition is the art of using meters and other test equipment.

A. Symptom recognition is the distorted sound from a receiver.

No. Realizing that the sound is not normal would be an indication which you should recognize. Remember if the output is not normal, this would be an indication of trouble somewhere in the equipment.

B. Symptom recognition occurs when I become aware of some undesirable change in equipment performance.

Your choice is correct. In choosing this answer, you have recognized the fact that when an equipment is not performing properly it will display some sign of poor performance. When you know that this sign exists, you have accomplished the first step of our troubleshooting procedure.

C. Symptom recognition is the art of using meters and other test equipment.

Absolutely incorrect. Nothing has been said about using meters and other test equipment. Certainly, troubleshooting requires skill in using test equipment, but unless there is a logical approach to trouble analysis, no amount of test equipment will solve the problem efficiently. If you were unable to recognize a trouble symptom, you would never get a chance to use the test equipment.

NORMAL AND ABNORMAL PERFORMANCE

Since a trouble symptom is an undesirable change in equipment performance, we must have some standard of normal performance to serve as a guide. By comparing the present performance with the normal, you can recognize that a trouble symptom exists and make a decision as to just "what" the symptom is.

Your normal body temperature is 98.6° Fahrenheit. A change above or below this temperature is an abnormal condition -- a trouble symptom. If you determine that your body temperature is 102° F., by comparing this with the normal you can say that the symptom is an excess temperature of 3.4° F. Thus, you have exactly defined the symptom.

The normal television picture is a clear, properly contrasted representation of an actual scene. It should be centered within the vertical and horizontal boundaries of the screen. If the picture

suddenly begins to "roll" back and forth vertically, you should recognize this as a trouble symptom because it does not correspond to the normal performance which is expected.

The normal sound from a superheterodyne receiver is a clearly understandable reproduction of the message sender's voice. If it sounds as though the sender is talking from the bottom of a barrel filled with water, the receiver operator knows that this distortion is a trouble symptom.

When performing step 1, symptom recognition, would you:

SELECTIONS:

A. Consider only the signs that indicates abnormal equipment operation.

B. Consider only the signs that indicate normal equipment operation.

C. Consider both normal and abnormal signs that indicate equipment operation.

A. Consider only the signs that indicate abnormal equipment operation.

You are wrong. Although symptom recognition requires that you consider the signs that indicate abnormal operation of the equipment, you must also consider the indications of normal operation. Your knowledge of the equipments operation will help when determining which symptoms are normal and which are abnormal. Together, the normal and abnormal signs more accurately pinpoint the trouble symptom than do either the normal or abnormal signs alone.

B. Consider only the signs that indicate normal equipment operation.

No. This is not absolutely correct. It is important to know what the normal symptoms are when the equipment is operating properly so that abnormal symptoms can be recognized. Your knowledge of the equipments operation will aid you in recognizing the fact that the equipment may not be operating as it should. A comparison with standard operation will provide the technician with important data in determining whether or not a trouble exists.

C. Consider both normal and abnormal signs that indicate equipment operation.

Good. You understand that although you do consider the signs that indicate abnormal equipment performance, you must also consider the signs that indicate normal operation. Without the latter there would be no basis for deciding which type of performance indicates trouble and which does not.

PERFORMANCE EVALUATION

During the process of doing their assigned job, most electronic equipments yield information which an operator or technician can either see or hear. The senses of hearing and sight, therefore, allow you to recognize the symptoms of normal and abnormal equipment performance. The display of information may be the sole job of the equipment or it may be a secondary job to permit performance evaluation.

Electrical information, to be presented as a sound, must be applied to a loudspeaker or a headset. A visual display results when the information is applied to a cathode-ray tube or to an indicating meter which is built into the equipment control panel and which can be viewed by the operator. Pilot lights also provide a visual indication of equipment operation.

As an example of how these various displays can be used to evaluate or "monitor" equipment performance, consider the plate current meter or "tuning meter" which monitors the plate current in the final

stage of a broadcast transmitter. When the transmitter is tuned to the proper frequency, there should be a "dip" in the plate current meter.

Tuning the transmitter corresponds to adjusting the capacitance of the parallel inductor-capacitor tank circuit so that the condition of parallel resonance exists at the desired frequency. The parallel resonance condition results in maximum impedance to plate current flow -- hence, a very low value of plate current. (The plate current meter would "dip" at this point.)

In the detuned condition, the plate current may be quite high, as shown in part A of figure 4. As the tuning control is adjusted to approach the proper frequency, the current will abruptly decrease, as shown in part B. The lowest reading (part C) will occur at the correct frequency if the equipment is performing normally.

Knowledge of the normal equipment displays will enable you to recognize an abnormal display, which provides the trouble symptom we are concerned with in our first troubleshooting step.

Which of the following selections is a description of how you can evaluate equipment performance?

SELECTIONS:

A. Observe the indicator lights on the equipment. If any are abnormal, perform checks on the various units of the equipment.

B. Pay close attention to the displays that the equipment itself produces and compare these displays against your knowledge of how the equipment should normally perform.

C. Operate the equipment controls until the equipment's displays correspond to what you know they should be.

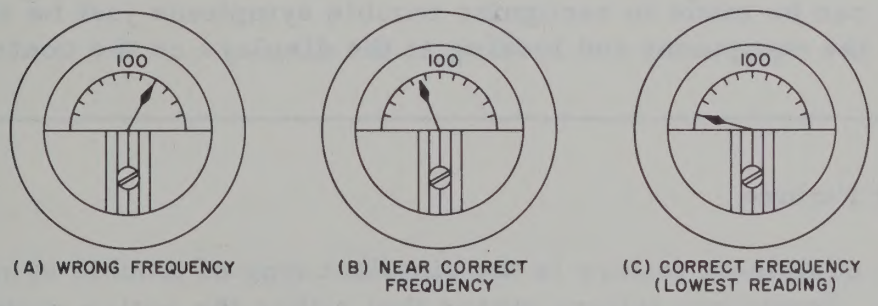

Figure 4. Plate Current Indications During Transmitter Tuning Process

A. Observe the indicator lights on the equipment. If these are abnormal, perform checks on the various units of the equipment.

No. You are evidently trying to work too far ahead. Before any checks can be made, you must realize that a trouble exists. Abnormal indicator lights may or may not be an indication of abnormal operation (the light may be defective; this would not necessarily effect equipment operation). The technician should observe all displays such as meter readings, displays, and indicator lights to determine if a trouble actually exists. Actual tests on the equipment units must wait until the proper place in the trouble-analysis procedure. The first step--symptom recognition--is accomplished without any tests whatever. The equipment itself will provide the necessary information for performance evaluation.

B. Pay close attention to the displays that the equipment itself produces and compare these displays against your knowledge of how the equipment should normally perform.

Yes. This will provide sufficient evaluation for you to recognize a trouble symptom. Symptom recognition is, after all, the sole purpose of step 1 in our trouble-analysis procedure. The idea is to correct faults as quickly as possible so that further damage is prevented.

C. Operate the equipment controls until the equipment displays correspond to what you know they should be.

No. The operation of controls is out during the first step--symptom recognition--of our trouble-analysis procedure. You must recognize or discredit the trouble symptom reported to you with all equipment controls in their original position. Otherwise you might upset the conditions which produced the initial trouble symptom. Sufficient evaluation can be made to recognize trouble symptoms just be standing in front of the equipment and looking at the displays on the control panel.

Equipment Failure

Electronic equipment failure is the simplest type of trouble symptom to recognize. Equipment failure means that either the entire equipment or some part of the equipment is not functioning and will, therefore, show no performance display.

The absence of sound from a superheterodyne receiver when all conrols are in their proper positions indicates a complete or partial failure. Similarly, the absence of a visible trace or picture on the screen of a cathode-ray tube when all controls are properly set points to some form of equipment failure. If you have observed the plate current reading on the tuning meter of a broadcast transmitter and the reading suddenly dropped to zero, you have observed an equipment failure.

Equipment failure can be recognized by:

SELECTIONS:

A. An undesirable cathode-ray tube display, or sound from a speaker.

B. A lack of performance information which would normally be seen or heard by the equipment operator.

C. A higher or lower than normal tuning meter reading.

A. an undesirable cathode-ray tube display, or sound from a speaker.

No. These audible and visual indications are certainly trouble symptoms, but they do not indicate equipment failure. If there were no sounds from the speaker or if the visual display was completely absent, then either some part, or the entire equipment has failed.

B. A lack of performance information which would normally be seen or heard by the equipment operator.

Very good. An electronic equipment must perform a job. In the process of performing this job, it must provide information which an operator can see and/or hear. If there is no such information, an equipment failure represents an extreme in abnormal performance. Undesirable indications are also trouble symptoms, buy they do not point to equipment failure. These indications fall into the next category of trouble symptoms.

C. A higher or lower than normal tuning meter reading.

No. Abnormal meter readings are indications of equipment troubles, but do not necessarily indicate the equipment has failed. If you were observing a radar screen and the screen suddenly went blank (no raster), this would be an indication that some part of the equipment had failed.

Degraded Performance

Even if the audible and visual information described in the previous section is present, the equipment may not be performing normally. Whenever the equipment is doing its job, but is presenting the operator with information that does not correspond with the design specifications, the performance is said to be degraded. Such performance must be corrected just as quickly as an equipment failure. This performance may range from a nearly perfect operating condition to the condition of barely operating.

If you were sick but still went to your regular duty assignment, the chances are your performance would be degraded for the period of your illness. However, you would still be performing your job, but not as well as it would if every component were operating properly.

All of the trouble symptoms presented in this lesson, with the exception of those given in the section, Equipment Failure, have been symptoms of degraded performance. These include distortion in the sound from a

superheterodyne receiver, the vertical "rolling" of a television picture, an incorrect meter reading, and an undesirable cathode-ray tube display. A reduction in radar range capability, as indicated when a search radar set which is designed to spot targets 50 miles away, is another example of a degraded-performance symptom.

Again, all of these indications are audible and/or visual. They can be recognized by comparing the normal equipment displays with the present operating displays with the present operating displays.

Figure 5 shows a basic Class A triode amplifier circuit. From your previous training you know that if pure sine-wave voltage (as shown in figure 5) is applied to the tube, a pure sine wave of larger magnitude should appear at the plate of the triode amplifier.

Assuming that the amplifier will provide a gain of 100, which of the wave-forms in figure 6 represents degraded performance?

SELECTIONS:

A. All of the waveforms.

B. Waveforms A and C.

C. Waveforms B and C.

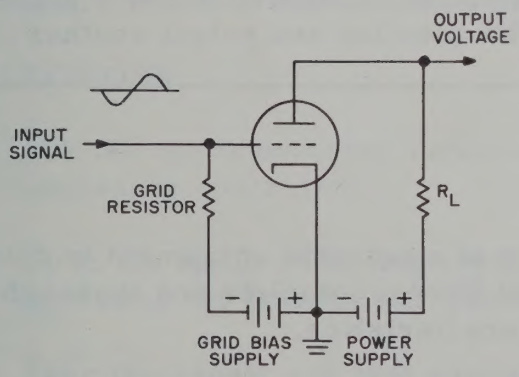

Figure 5. Basic Triode Amplifier

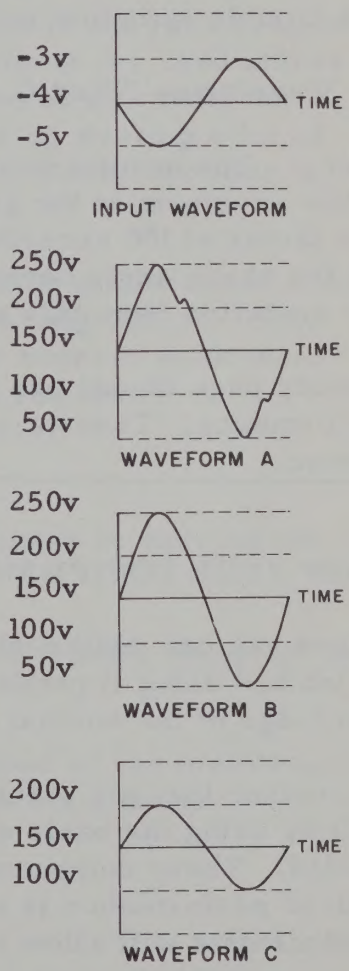

Figure 6. Output Waveforms

A. All of the waveforms.

Come now - the normal waveform at the plate should have exactly the same shape as the waveform applied to the grid of the triode. The amplitude will change, and the waveform will be 180 degrees out of phase with the input waveform. Degraded performance does not meet the standards set up for a particular piece of equipment. If distortion occurs the equipment is not operating properly.

B. Waveforms A and C.

Congratulations. By selecting this answer you have shown your ability to recognize that a degraded performance symptom exists whenever the present performance deviates from the normal performance as specified for the equipment in question. In this case the waveform should have been a perfect sine wave with a peak amplitude of 100 volts and 180 degrees out of phase with the input. Any other waveform would be a trouble symptom in the degraded-performance category.

C. Waveforms B and C.

Wrong. The normal waveform across R_L should have the same shape as the waveform at the grid of the tube. The amplitude will be changed by a factor of 100 according to the information given in the question, and the phase angle between the input and output will be 180 degrees. Any deviation from this normal condition shows degraded performance.

Restudy page 22 and pay particular attention to the definition of degraded performance. Then carefully study the question and select another answer.

KNOW YOUR EQUIPMENT

Before you can decide whether a piece of electronic equipment is doing its job and doing it properly, you must have a complete and thorough knowledge of the normal operating characteristics.

Remember that any electronic equipment, no matter how complex, is built by using the basic electronic circuits and devices you have already studied. These components are combined in such a manner that the desired performance is produced. Therefore, a knowledge of electronic fundamentals will allow you to analyze the performance of any equipment.

This basic knowledge can be supplemented by consulting the equipment handbooks, instruction books, and maintenance directives associated with each piece of equipment. The instruction manual for the TS-O included in volume 3 of this Automated Text is an example of such a publication.

The information you need to evaluate equipment performance must be provided by audible or visual displays on the equipment control panel(s). However, unless you can apply your knowledge of the equipment in interpreting these displays, their existence will be meaningless.

From the information contained in this lesson, you have probably come to the conclusion that the equipment operator is in a better position to recognize an initial trouble symptom than you are. This is true. Most of the first indications of trouble will be reported to you by an equipment operator. However, this does not mean that you do not need to know operation of the equipment just as well as he does.

Operating the equipment under normal conditions is not your responsibility--but operating it under abnormal conditions is. And unless you can employ your own knowledge to recognize or discredit the reported trouble symptom, you are going to end up wasting a lot of time by getting yourself involved in unnecessary troubleshooting projects.

Assume that you have recently completed a routine maintenance check of your ship's transmitter. You found nothing wrong with it. Yet, only a few days later one of the radio operators reports weak transmission. Which of the following actions should you take?

SELECTIONS:

A. Ask the operator to try retuning the transmitter by varying the necessary controls.

B. Go to the radio room and verify the reported trouble symptom by operating the transmitter yourself.

C. Take the repair and test equipment prescribed by the maintenance manual and begin testing procedures to locate the fault.

A. Ask the operator to try retuning the transmitter by varying the necessary controls.

No. The operator has been trained to recognize whether or not his equipment is operating properly. The information he provides is important and should be considered by the technician when formulating his List of Probable Faulty Functions, but the technician has been trained to recognize the faulty symptoms that are indicated by faulty meter readings, distortion from a loud speaker, or an erratic display on the cathode-ray tube.

B. Go to the radio room and verify the reported trouble symptom by operating the transmitter yourself.

Very good. From the equipment operator's statement, apparently something has gone wrong. In order to adhere to the logical steps of the troubleshooting procedure, you must first verify and study the trouble symptom yourself before jumping to conclusions.

C. Take the repair and test equipment prescribed by the maintenance manual and begin testing procedures to locate the fault.

Hold on there! What is the first step in our logical approach to trouble analysis? Symptom recognition requires that you must examine the reported symptom. If you begin testing procedures, you would not be following a systematic approach. It isn't that we are attempting to downgrade your faith in your fellow man, but when it comes to trouble analysis do not take someone's word for it--investigate the report yourself.

You should know the equipment well enough to examine the supposedly faulty transmitter and decide whether the performance shows a trouble symptom. After investigating the symptom yourself, you may decide to get your tools and repair the equipment in the radio shack or if the equipment is small enough you may decide to take it down to the shop. You may also prove that the trouble symptom does not exist, saving yourself a lot of unnecessary work.

Now let us summarize this lesson. Symptom recognition, or recognizing failure and degraded performance in electronic equipment, forms the first step of any troubleshooting procedure. In order to be aware of symptoms, you must have a knowledge of the present operating characteristics and the design-performance normal characteristics of the equipment.

STEP 2. SYMPTOM ELABORATION

Breaking out the test equipment and equipment diagrams and proceeding headlong into testing procedures on just the original recognition of a trouble symptom is an unrealistic approach. Unless you completely define a trouble symptom first, you can quickly and easily be led astray. The result, as before, would be loss of time, unnecessary expenditure of energy, and perhaps even a total dead-end approach.

Symptom elaboration is the process of obtaining a more detailed description of the trouble symptom. Recognizing that the fluorescent screen of a cathode-ray tube is not lighted is not sufficient information for you to decide exactly what could be causing the trouble. This symptom could mean that the cathode-ray tube is burned out, that there is some disorder in the internal circuitry associated with this tube, that the intensity control is turned down too low, or even that the equipment is not turned on. Think of all the time you may waste if you tore into the equipment and began testing procedures when all you may need to do is flip the "on-off" switch to "on", adjust the intensity control, or just plug in the main power cord.

Similarly, recognizing an undesirable hum in a superheterodyne receiver as a trouble symptom could lead you in several directions if you do not obtain a more detailed description of the symptom. This receiver hum may be due to poor filtering action in the power supply, heater-cathode leakage, a-c line voltage interference, or other internal and/or external faults.

It should be apparent by now that the primary reason for placing symptom elaboration as the second step in our logical procedure is that many similar trouble symptoms can be caused by a large number of equipment faults. In order to proceed efficiently, it is necessary to make a valid decision as to which fault(s) is probably producing the specific symptom in question.

Which of the following best describes symptom elaboration?

SELECTIONS:

A. Symptom elaboration is the process whereby I will list all the possible causes of the original trouble symptom.

B. Symptom elaboration is the process I must accomplish in order to obtain more information about a trouble symptom.

C. Symptom elaboration is the process of collecting additional information by the use of test equipment.

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A. Symptom elaboration is the process whereby I will list all the possible cuases of the original trouble symptom.

Definitely not. In order to increase your efficiency as a troubleshooter, you must make a valid decision as to what is the most probable cause(s) of the symptom. Recognizing the original symptom does not usually provide sufficient information for making this decision. Elaborating on the symptom will provide this information.

B. Symptom elaboration is the process I must accomplish in order to obtain more information about a trouble symptom.

Exactly. The recognition of the original trouble symptom does not, as a rule, provide sufficient information to decide on the probable cause(s) of the symptom because many faults produce similar trouble symptoms.

Without being able to make valid decisions as to the probable cause(s), you cannot go to the next step in our procedure, and you will not be a very effective or efficient troubleshooter.

In order to elaborate upon a trouble symptom, you will have to manipulate the equipment controls associated with the symptom.

C. Symptom elaboration is the process of collecting additional information by the use of test equipment.

Hold on now - You are in too much of a hurry. Your use of test equipment will come later on. First you must determine where these tests should be made. To do this, use your powers of observation while manipulating controls of the equipment.

IMPROPER USE OF OPERATING CONTROLS

Operating controls are considered to be all front panel switches, variable circuit elements, or mechanical linkages connected to internal circuit components which can be adjusted without going inside the equipment enclosure. These are the controls which the equipment operator must "operate" in order to supply power to the equipment circuits, to tune or adjust the performance characteristics, or to select a particular type of performance.

By their very nature, operating controls must produce some sort of change in the circuit conditions. This change will indirectly alter current or voltage values by the direct variation of resistance, inductance, and/or capacitance elements in the equipment circuitry. The information displays associated with the equipment--front panel meters and other indicating devices--will enable you to "see" the changes which take place when the controls are operated.

Maximum Design Ratings

Control manipulation can cause detrimental effects in equipment performance, as well as the desirable effects for which they are primarily intended. Manipulating controls in an improper order or allowing voltage and current values to exceed maximum design specifications may have resulted in the damage which brought about the original trouble symptom. Unless you observe the proper precautions while investigating the symptom, the improper use of operating controls can result in even more damage to the equipment.

Every electronic circuit component has definite maximum current and voltage limits below which it must be operated in order to prevent "burn out" or insulation breakdown. The meters placed on the front panel of electronic equipments serve as an aid in determining voltage and current values at crucial points in the equipment circuitry. Operating controls should never be adjusted so that these meters indicate values above the maximum ratings.

When you are investigating a trouble symptom, which of the following selections should be uppermost in your mind as a possible cause of equipment damage?

SELECTIONS:

A. Shock and vibration produced by other equipment in the vicinity of the equipment being checked.

B. Operating controls were adjusted in such a way that the component maximum ratings were exceeded.

C. Equipment operators are an ill-trained group.

A. Shock and vibration produced by other equipment in the vicinity of the equipment being checked.

No. Under combat conditions it is possible that excessive shock and vibration encountered during engagements with the enemy may produce equipment damage. However, under normal operating conditions equipment is designed to withstand the vibration produced by nearby equipment. The effect of vibration is also considered in the over-all layout of the equipment room.

B. Operating controls were adjusted in such a way that the component maximum ratings were exceeded.

Yes. This can easily be the cause of equipment damage, and you should keep this fact in mind. By doing so you not only may find the solution to your troubleshooting problem, but also may keep yourself from producing more damage through your own carelessness.

C. Equipment operators are an ill-trained group.

Absolutely incorrect. An equipment operator is just as well trained in his duties as you are in your duties. Anyone can make a mistake or perform a careless act occasionally. Continious carelessness (by the operator or technician), however, is inexcusable, and you can prevent this by reminding the careless person of his duties and responsibilities if he is overly careless.

Precautions for Specific Equipment

In addition to exceeding maximum ratings and manipulating controls in an improper sequence, there are certain other precautions associated with specific types of equipment.

For example, an intensity control on an oscilloscope should never be adjusted to produce an excessively bright spot on the fluorescent screen. A bright spot indicates a high current which may burn the screen coating and decrease the life of the tube. Also, for the same reason, you should never permit a sharply focused spot to remain stationary for any length of time.

Another precaution concerns the adjustment of a range selector switch on any type of indicating meter. If the switch is carelessly positioned to a range below the value of the quantity being measured, the needle

will strike its upper mechanical limit. This may bend the needle and result in inaccurate (offset) readings.

It would be impossible within the scope of this book to list all the precautions associated with the various equipments. The examples above are included to increase your recognition of the importance of these precautions.

A knowledge of the circuit changes that take place when you adjust a control will enable you to think ahead of each step and to anticipate any damage which the adjustment might produce. Do not reach to make an adjustment in haste or panic.

Remember that any damage resulting from the improper use of operating controls will probably have to be repaired by you. You can save a lot of unnecessary troubleshooting time by exercising care when you are at the controls and by impressing this fact upon the equipment operator whenever the need is indicated.

In view of this discussion, which of the following facts should be kept in mind when adjusting operational controls?

SELECTIONS:

A. I should set all controls to zero and advance each in small steps.

B. I should memorize all of the operating precautions listed in the manuals covering the equipment for which I am responsible.

C. By realizing that certain precautions must be taken when manipulating operating controls, I can prevent damage to equipment through my own carelessness and possibly determine the cause of damage to the equipment I must repair.

A. I should set all controls to zero and advance each in small steps.

This is not correct. When making voltage measurements, for example, the range control should be set to the highest scale if the voltage is unknown. It may also be necessary to set an attenuation control to a level other than zero prior to energizing the equipment. Knowledge of the specific equipment will help you in determining how much a control can be changed without detremental effects.

B. I should memorize all of the operating precautions listed in the manuals covering the equipment for which I am responsible.

No. First of all, this would probably be an impossible task; secondly, whenever you are transferred, given different duties, or assigned new equipment, you would have to memorize new precautions. The idea is to anticipate the improper handling of controls by using your basic knowledge and to consult a manual when you are in doubt.

C. By realizing that certain precautions must be taken when manipulating operating controls, I can prevent damage to equipment through my own carelessness and possibly determine the cause of damage to equipment I must repair.

Good. Keep this in mind and you will have mastered an important troubleshooting technique. Operating controls can be varied small amounts without damage to the equipment. Normal precautions taken when manipulating these controls will prevent damage to the equipment. Rely on your basic knowledge and consult manuals whenever you are in doubt.

FURTHER DEFINING THE SYMPTOM

The first step of our procedure--symptom recognition--(Lesson No. 2) required adequate knowledge of equipment operation before you could be "aware" of a trouble symptom. This knowledge is to be assumed throughout the remaining steps of the logical trouble-analysis procedure. It cannot be over-emphasized that knowledge of how an equipment works and a systematic approach to troubleshooting have equal importance, and that possessing one of these factors alone is not sufficient.

The purpose of symptom elaboration is to enable you to fully understand what the symptoms are and what they truly indicate. This elaboration is required in order to gain further insight into the problem.

Incorrect Control Settings

Incorrect operating control settings will produce an apparent trouble symptom. We use the word apparent because the equipment may be operating perfectly, but, because of the incorrect setting, the information display will not correspond with the expected performance.

An incorrect setting may be brought about by an accidental movement of the control, as well as careless misadjustment. The discovery of such an incorrect setting permits sufficient "elaboration" of the trouble symptom to "fix" it immediately, thereby ending your troubleshooting project if you can verify that the incorrect setting was the only cause of the trouble symptom.

Why can the discovery of an incorrect control setting be considered a part of symptom elaboration?

A. It will allow me to correct the trouble symptom and terminate my troubleshooting project.

B. It provides additional information about the trouble symptom.

C. It will indicate that a particular unit has been damaged due to the incorrect setting.

A. It will allow me to correct the trouble symptom and terminate my troubleshooting project.

No. This statement may be true, but it does not tell why locating an incorrect control setting falls under the step--symptom elaboration. Furthermore, your troubleshooting project is not terminated just by re-positioning the control. First you will have to verify that this is the sole cause of the trouble symptom.

B. It provides additional information about the trouble symptom.

Absolutely correct. This is the basic definition of symptom elaboration. The additional information provided may allow you to terminate your troubleshooting project by repositioning the control if you can verify that this is the only cause of the trouble symptom.

C. It will indicate that a particular unit has been damaged due to the incorrect setting.

No. The incorrect setting of a control could result in damage to a particular unit but usually results in degraded performance or possibly no output. Correcting the setting of the control usually places the equipment in normal operating condition.

Example Situation. Assume that you are checking the voltage across the load resistor of an audio amplifier stage in a superheterodyne receiver with an oscilloscope. The waveform should be 100 volts from the positive peak to the negative peak, and you are trying to verify this amplitude in order to evaluate the amplifier stage performance.

You intend to set the vertical sensitivity switch to 50 volts per centimeter and consequently expect to see a display waveform similar to that shown in figure 7, part A. However, in haste you accidentally set the vertical sensitivity switch to 10 volts per centimeter. As a result of this carelessness, the display you see is actually similar to that of part B in the figure, and at first glance, you assume the amplitude is 500 volts since you think the switch is set at 50 volts per centimeter. Certainly, the first thought to enter your mind is that the amplifier is not functioning properly.

At this point your knowledge of amplifier operation should be applied. Figure 8 is the circuit diagram for the amplifier you are checking. Immediately you should realize that, since the supply voltage for the amplifier is only 150 volts, it is an operational impossibility for 500 volts to exist across the load. The amplifier shown in the figure cannot produce an output voltage larger than its own plate supply voltage.

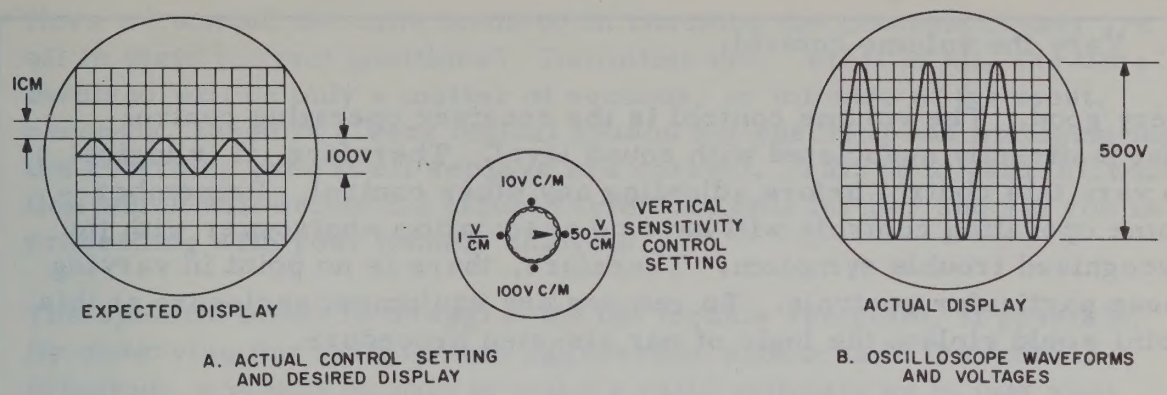

Figure 7. Oscilloscope Waveforms and Voltages

The next logical assumption is that the oscilloscope is in error. Since it is the vertical dimension which is apparently in error, this should immediately direct your attention to the vertical sensitivity control. Once you discover the error in control setting, you will realize that the display actually represents 100 volts peak-to-peak. Therefore, there is no real trouble symptom.

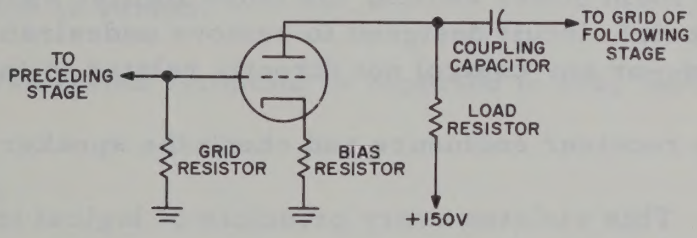

Figure 8. Typical Audio Amplifier Stage

This application of equipment knowledge and logic should have enabled you to discover the error in less time than it took you to read this section. This represents a considerable savings over the time that would have been consumed if you had torn into the amplifier or oscilloscope looking for a non-existent fault.

An equipment operator has reported a very low sound level on the ship's superheterodyne receiver. You go to the radio shack and verify that this symptom exists. What is the next action you should perform?

SELECTIONS:

A. Vary the volume control.

B. Vary all the receiver operating controls.

C. Remove the receiver enclosure and check the speaker connections.

A. Vary the volume control.

Very good. The volume control is the receiver operating control that is directly associated with sound level. Therefore, it is logical to vary this control before adjusting any other control. Remember--some operating controls will have no association whatsoever with the recognized trouble symptom. Therefore, there is no point in varying these particular controls. To remove any equipment enclosure at this point would violate the logic of our six-step procedure.

If varying the volume control in this problem produces the proper sound response and if you can verify that the operator's failure to manipulate this control is the sole cause of the symptom, your job is finished. If not, you still need more information.

B. Vary all receiver operating controls.

No. Your first action should not be to vary all the receiver operating controls--that is too broad a step. Obviously the receiver is operating so why vary the main power switch, the noise limiter switch--which activitates a special circuit designed to remove undesirable noise in the received signals--or any control not directly related to the sound level?

C. Remove the receiver enclosure and check the speaker connections.

Absolutely not. This violates every principle of logical trouble analysis. At this point you have absolutely no reason to suspect loose speaker connections as the cause of the symptom. You must proceed logically in order to be an efficient troubleshooter, as well as to gain the confidence necessary to become a top-notch troubleshooter.

Aggravating the Trouble Symptom

If all controls are set at their correct positions but the symptom persists, it is still possible that an operating control is responsible for the trouble symptom. However, in this case the trouble would have to fall in the general area of component failure. If a control is faulty, this may be immediately apparent--especially when it is a mechanical failure. However, additional information may be required to determine when a control has failed electronically since the trouble symptom produced may also point to other electronic failures.

Have we wasted the time involved in checking the controls if they are all in their correct positions? Definitely not. First of all, the time involved will be only a matter of seconds, or minutes at the most. Secondly, there is a very logical reason for checking and manipulating the controls, even if all settings are correct. This is to gain information which will define the trouble symptom still further and aid you in proceeding with your trouble analysis.

The specific intent is to aggravate the trouble symptom, if possible. By observing the changes this aggravation produces in the trouble symptom, you will be able to make a valid estimate as to just what is probably causing the panel meter readings and the displays produced by other front-panel devices, such as cathode-ray tube screens and indicator lights.

As an example, consider the frequency range switch on a broadcast transmitter. This control is a multi-position switch with each position connecting a different r-f coil in parallel with the main tuning capacitor of the oscillator tank circuit. The value of each coil is such that it will cause the oscillator to vary over a different range of frequencies as the tuning capacitor is varied.

If a weak transmission symptom is reported to you, would it be logical to:

SELECTIONS:

A. Assume that the operating controls are satisfactory and look elsewhere for the trouble.

B. Assume that the weak transmission is due to a weak oscillator tube.

C. Try another frequency range by manipulating the selector switch.

A. Assume that the operating controls are satisfactory and look elsewhere for the trouble.

No. The manipulation of the controls may indicate that the equipment operates satisfactory in one mode or phase but not in another. This would limit the trouble symptom to a particular area.

B. Assume that the weak transmission is due to a weak oscillator tube.

Although a weak oscillator tube could result in a low output, this is not the next logical step. Manipulation of the controls can provide additional answers prior to localizing the trouble symptom.

C. Try another frequency range by manipulating the frequency switch.

Good. If normal transmission is achieved for any of the range positions, the fault must lie either in the switch itself or in only a few (perhaps only one) of the tuning coils. Such a discovery would provide a quick location of the trouble area.

Further Aggravating the Trouble Symptom

Similarly in a receiver, if a mode selector switch can be changed from AM operation to FM operation, it is logical to check the receiver in both positions. If the symptom persists only in the AM mode, the circuitry associated with the FM mode can be eliminated as a probable cause later in our troubleshooting procedure.

If a broadcast transmitter uses plate modulation to add the information signal (voice) to the r-f signal, the degree of modulation will be controllable by a front panel knob. The modulating signal is applied to the plate circuit of the r-f amplifier through a coupling transformer. Between the input of this transformer and the microphone that gathers the voice information is an audio amplifier. The modulation control may vary the gain of this amplifier; hence, any additional undesirable changes in the trouble symptom produced by varying this control would point to faults in the audio units which precede the modulation transformer.

The examples above represent only a small portion of the various controls associated with a transmitter or receiver. The controls and instrumentation associated with every type of equipment are specifically incorporated to provide information about that particular device. Therefore, it is necessary to understand the operation of the equipment in

order to appreciate the aid which can be obtained by manipulating controls.

Which of the following selections best describes the reason for checking and manipulating the operating controls when a trouble symptom has been recognized.

SELECTIONS:

A. It allows me to determine whether the controls are set to their correct positions and whether they are operating properly.

B. The trouble symptom may have been caused by an incorrectly set control. If not, the effect of manipulating the control may aid in locating the trouble.

C. There has to be some place to start, and manipulating the controls is as good as any. Besides this only takes a few minutes and some information may be gained.

A. It allows me to determine whether the controls are set to their correct positions and whether they are operating properly.

This statement is true; however, it does not fully answer the question. The best description should include all of the factors which make the manipulation of controls the most logical and important first action when elaborating on a trouble symptom.

B. The trouble symptom may have been caused by an incorrectly set control. If not, the effect of manipulating the control may aid in locating the trouble.

Correct. Symptom elaboration is based upon the manipulation of operating controls and the interpretation of front-panel meter readings. This action will result in finding an incorrect switch setting and correcting it, or finding a faulty control and replacing it, or obtaining more information about the trouble symptom. This last result will enable you to make a valid estimate of "where the fault is located" and can save you a lot of valuable troubleshooting time. Adding to the logic behind making this first action after symptom recognition is the fact that front-panel controls and instruments are readily accessible.

C. There has to be some place to start, and manipulating the controls is as good as any. Besides this only takes a few minutes and some information may be gained.

Positively incorrect. The manipulation of controls is logically the best place to start in symptom elaboration. Several very good reasons for this logic have been discussed.

Return to page 32 and restudy all of the material presented, starting with FURTHER DEFINING THE SYMPTOMS. A thorough understanding of the material following this page is necessary for a continuation of this book.

DATA RECORDING AND ITS PURPOSE

Symptom elaboration cannot be fully accomplished unless the observed displays can be completely evaluated. This means that the indications must be evaluated in relation to one another, as well as in relation to the over-all operation of the equipment. The easiest method for accomplishing this evaluation is to have all data handy for reference by recording the information as it is obtained.

This will enable you to sit back a moment and "think" the information over before jumping to a conclusion as to where the trouble lies. It will also enable you to check the equipment manual and compare the information with detailed descriptions if this is necessary--a particularly useful technique for someone just becoming familiar with troubleshooting. Finally, by recording all control positions and the associated meter and indicator information, you can quickly reproduce the information and check to see that it is correct, as well as put the equipment in exactly the operating condition that you wish to test. Thus the recording of information will enable you to save time and become a more efficient troubleshooter.

Whenever the adjustment of a control has no effect upon the symptom, this fact should also be recorded. This information may later prove to be just as important as any changes a control may produce in the trouble symptom.

This procedure may seem unnecessary as this portion of the text is read, but it will definitely pay off in systematic trouble analysis. This fact will become more obvious as future lessons are studied and we probe deeper and deeper into the equipment under test.

Which of the following selections best describes the reason(s) for recording all of the data obtained during the symptom elaboration step?

SELECTIONS:

A. It permits an over-all analysis of the information obtained during the symptom elaboration step.

B. It permits the technician to maintain a complete record of the failure for future reference.

C. It permits a complete analysis of all pieces of information in their proper importance and permits the recreation of specific performance characteristics when this is necessary.

A. It permits an over-all analysis of the information obtained during the symptom elaboration step.

Wrong. This selection states the reason for recording data, but it does not tell the complete story. What would happen if the meters were read incorrectly?

B. It permits the technician to maintain a complete record of the failure for future reference.

No. Although a record of past failures may prove useful in some cases, a logical approach will certainly prove more useful. Except in cases where the same trouble repeats itself many times and is due to a faulty design, the same trouble does not normally reoccur.

C. It permits a complete analysis of all pieces of information in their proper importance and permits the recreation of specific performance characteristics when this is necessary.

This is the correct choice. Being able to refer to this information later may save time and result in a much more thorough solution to the fundamental problem. Saving time and permitting you to proceed in a confident and efficient manner is the core of our second step--symptom elaboration.

Gaining further information about a trouble symptom by manipulating the operating controls and instruments will help you identify the probable faulty function required in the next step. This procedure will give you an estimate of where the trouble lies and will permit you to eventually classify the problem down to the exact item responsible.

If the trouble is cleared up by manipulating the controls, the trouble analysis may stop at this point. However, by using your knowledge of the equipment involved, you should find the reason why the specific control adjustment removed the apparent malfunction. This action is necessary to assure yourself, as well as the operator, that there no additional faulty items which will produce the same trouble later.

In manipulating controls, you must be aware of the circuit area in which the control is located. Only those controls that will logically affect the indicated symptom should be adjusted. When adjusting controls, use extreme caution--a misadjustment may cause additional circuit damage.

Whether or not you will proceed from step 2 to step 3 (listing of probable faulty functions) or to step 5 (localizing trouble to the circuit) will depend on the number of units in the equipment and/or the complexity of a single-unit equipment, as described in Lesson No. 1.

Remember--step 2 (symptom elaboration) is the "I need more information step." Use it as such and record all important information about operational adjustments and indications. Now turn to page 45 and begin the lesson on step 3.

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STEP 3. LISTING OF PROBALBE FAULTY FUNCTIONS

As we pointed out in the block diagram of our six-step procedure (fold-out page 1), the performance of the third step is dependent upon the information gathered in the two previous steps. Step 1, remember, was "symptom recognition", that is, becoming aware of the fact that an equipment is performing its operational function in an abnormal manner. Step 2 symptom elaboration allows you to use the operating controls and front-panel indicators to obtain as much information about the abnormality as you possibly can.

Step 3 listing of probable faulty function is applicable to equipments that contain more than one functional area, or unit. It allows you to mentally select the functional unit (or units) which probably contains the malfunction, as indicated by the information obtained in steps 1 and 2. The selection is made by stopping to think "Where can the trouble logically be in order to produce the information I have gathered?"

The term, function, is used here to denote an electronic operation performed by a specific area (or unit) of an equipment. A transceiver, for example, may include the following functional areas: transmitter, modulator, receiver, and power supply. The combined functions cause the equipment to perform the electronic purpose for which it was designed.

Frequently, the terms "function" (an operational sub-division of an equipment) and "unit" (its physical sub-division) are synomous. A functional unit may be located in one or more physical locations. For example some components of a receiver, in a transceiver set, may be located in the transmitter compartment. Normally the physical location, such as a drawer containing a receiver, is referred to as a "unit". Functional unit consists of all the components that are required for the unit to perform its function, whether these components are packaged in an individual drawer or in two drawers. Within this text the two terms, function and unit, will be used interchangeably, although in some equipments one or more circuits of a given function may have been built into a unit other than that bearing the title of the function.

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You cannot converse with the set the way a doctor converses with his patient and ask where it "hurts." You must determine this directly by surveying the information you have gathered and by using your knowledge of how the set works electronically. Here you will be aided by the technical manual's description of equipment operation.

The decision you reach (your selection) must be technically valid. To randomly select a functional unit as the one containing the malfunction would be fool-hardy and would lead to wasted time and energy. Competence in making the selection depends on logic and sould technical thinking. Several examples will be given as we proceed through this lesson.

What does our third step "listing of probable faulty functions" accomplish?

SELECTIONS:

A. This step pinpoints the faulty areas within the equipment so that I can proceed efficiently.

B. This will permit me to utilize my knowledge of how the equipment operates.

C. This step helps me mentally locate the probable trouble area so that I may proceed efficiently.

A. This step pinpoints the faulty areas within the equipment so that I can proceed efficiently.

Absolutely not. The purpose of this step is not to allow you to locate the faulty area within the equipment. This actual location will come later and will require extensive testing inside the equipment enclosure. Step 3 is still a preliminary to removing the equipment enclosure.

B. This will permit me to utilize my knowledge of how the equipment operates.

No. The accomplishment of every step in our six-step procedure will require equipment knowledge. No step is specifically designed so that you can "utilize" this knowledge more than you would in the other five steps.

C. This step helps me mentally locate the probable trouble areas so that I may proceed efficiently.

Correct. Listing of Faulty Functional Function are estimates of probable trouble areas within a multi-unit equipment. These selections are soundly supported by the information you have collected and your knowledge of equipment operation. This allows you to take the recorded data of step 2, which tells you "what is happening," and form a mental picture of "where it is happening."

Selection Logic

Faulty unit or function selection requires the use of logic similar to that employed by a medical doctor, auto mechanic, or other "technical doctor" when he searches for the cause of an illness or malfunction.

Assume that you are continually plagued with headache and you finally go to a doctor. If the doctor elaborates on the symptom by checking your eyes, ears, nose, and throat taking your temperature, and listening to your heartbeat, but then promptly sends you to the operating room to have your foot amputated, you would certainly question his diagnosis. Instead of taking such an illogical step, the doctor will decide on the basis of his examination, whether the most probable trouble is poor eyesight, a sinus infection, or some other logical disorder. Only after making such a decision will the doctor prescribe a possible remedy.

Similarly, the electronics technician who accomplishes the first two steps of our six-step procedure and then picks just any test or repair procedure in an attempt to correct the trouble is indeed a poor trouble-shooter. He must first survey the information he has gathered; then, using his knowledge of equipment operation along with the aids provided in the applicable technical manuals, he must make a technically sound decision as to what is probably causing the recorded symptoms.

The millions of cells and thousands of parts in the human body could provide a considerable complication to the medical doctor when he is making his diagnosis if he had to check each part or each cell separately to find the exact cause of the illness. Instead, he divides the body into functional groups, each containing many associated parts. He then associates the symptoms of the illness with the normal performance of the functional groups. Any indication of abnormal performance provides him with a clue to the exact cause of the illness.

The abnormal performance indications you noted in steps 1 and 2 should also give you clues as to the probable location of an electronic malfunction. Electronic equipment can have as many as 10,000 circuits, or 70,000 individual parts. The probability of finding the faulty part by methodically checking each of the 70,000 parts in turn is highly remote. The size of the task can be reduced by a factor of seven by checking the outputs of each circuit rather than checking each part separately.

However, 10,000 tests is still a job of considerable magnitude. By dividing the 10,000 circuits into their normal groupings of electronic functional units--seven, a dozen, or two dozen--you can reduce the job to a practical number of tests. Whether the equipment contains thousands, hundreds, or just a few circuits, logical reasoning dictates that the troubleshooting problem can be resolved more quickly and accurately by reducing the total circuits into a small number of groups.

Let's assume that we've divided the 10,000 circuits into 12 functional units. Locating the faulty unit might require 12 output tests unless you were lucky enough to find it before all units were tested. This still represents a departure from our basic logic. Why should the doctor amputate your foot if you had a sinus headache? Why should you test the turntable of a radio-television-phonograph console set if the picture on the TV tube is bad? You can predict that the trouble lies in the television receiver unit and confine your tests to that unit.

Which of the selections below provides the fundamental reason for having step 3--listing probable faulty function in our six-step troubleshooting procedure?

SELECTIONS:

A. It permits easy identification of circuit groupings.

B. It is a logical, time-saving step.

C. It permits me to make a test of the faulty circuit.

A. It permits easy identification of circuit groupings

No. Convenient circuit groupings are essential to accomplishing step 3 as well as all of the following steps. However, the easy identification of circuit groupings is a matter of experience and has nothing to do with placing step 3 in our six-step troubleshooting procedure.

B. It is logical, time-saving step.

Yes. It is time-saving because it permits you to test a few functional units rather than all functional units. It is logical because each unit has a definite functional purpose(s) that can be used, along with the data obtained in symptom recognition and elaboration, to predict the unit or units containing the trouble.

C. It permits me to make a test of the faulty circuit.

No. In the process of making checks, you will certainly test the faulty circuit, but this is not the reason for inserting this step. Our entire procedure is based on a logical reduction of the areas in which the trouble could be located. This reduction is planned so that the actual malfunctioning part - whether a resistor, capacitor, inductor, vacuum tube, or semiconductor - can be located with the least number of tests.

The Functional Block Diagram

Naval electronic equipments and sets are subdivided into functional units. Each functional unit is generally contained within a single case or box or, in some instance, within drawers arranged in a rack comprising the over-all set. The term functional is applied to these units because each one accomplishes a specific electronic function. The units are interconnected so that the individual functions will be performed in the proper sequence to accomplish the over-all operational function of the set.

The equipment functional block diagram is an over-all symbolic representation of the functional units within the equipment, as well as the signal flow paths between them.

Figure 9 (fold-out page 2) shows a typical functional block diagram. This particular diagram is for an AM transceiver set composed of six separate units. Each unit performs an electronic function and conforms to the input-conversion-output concept universally applied to all electronic circuits, units, and sets. Briefly, the function of each unit is:

1. The sound pickup unit (microphone) changes (converts) the sound information (input) to be transmitted into an electrical signal (output) of audio frequency (af).

2. The modulator unit amplifies the a-f signal and applies it to the transmitter in such a manner as to cause the amplitude of the r-f carrier signal to vary at an audio rate.
3. The transmitter unit provides the r-f signal, as well as the proper "boost" for the power in the AM signal, to achieve the desired transmission range.
4. The antenna assembly unit converts the electrical AM signal into electromagnetic energy suitable for transmission through the atmosphere. When the transceiver is serving as a receiver, this unit converts the electromagnetic energy transmitted from another location into electrical signals to be applied to the receiver unit.
5. The receiver unit converts the AM signal received from another into sound.
6. The power supply unit converts the line voltage into a low-value a-c voltage suitable for heating the filaments of the tubes within the set and into a d-c voltage suitable for operating the various units.
Note: Return fold-outs to their original positions when they are not in continous use.

There is no indication in the equipment functional block diagram as to how each function is accomplished. Thus, each functional unit may consist of a variety of circuits or stages, each performing its own electronic function. For example, the transmitter unit may contain an r-f oscillator stage, a voltage amplifier stage, and several power amplifier circuits.

Notice that the connecting lines between the various functional blocks represent importnat signal flow connections, but that the diagram does not necessarily indicate where these connections can be found in the actual equipment circuitry.

From the selections below, which one best describes the information provided by a functional block diagram?

SELECTIONS:

A. This diagram provides a picture aid for locating the functional units within a piece of electronic equipment.

B. This diagram provides a general picture of the major functional units of the equipment, as well as their important signal relationships.

C. This diagram shows the circuits to indicate how a function is accomplished.

A. This diagram provides a picture aid for locating the functional units within a piece of electronic equipment.

No. There is no relationship whatsoever between the physical location of the units within the equipment and the block arrangement in the functional block diagram. Frequently each block will represent a separate physical unit (located in a drawer or cabinet by itself). The diagram traces only the important signal paths through the functional units of the equipment.

B. This diagram provides a general picture of the major functional units of the equipment, as well as their important signal relationships.

Good. Equipment functional block diagrams show the functional relationships between the units of an equipment. The give you a general view of the functions that the equipment must accomplish in order to perform its designed task. This picture, along with the information about the trouble symptom you have collected and your equipment knowledge, provides a sound basis for making valid faulty unit selections. There is no need for test information such as test point locations, voltage and resistance values, etc, at this point in our six-step procedure. Furthermore, there is no relationship between the block diagram arrangement on this diagram and the physical location of the units that make up the equipment.

C. This diagram shows the circuits to indicate how a function is accomplished.

No. The diagram shows only a block indicating a particular function performed, but does not show the circuits that accomplish the function. Each function may be accomplished by a few or many circuits, depending upon the function performed.

FORMULATING A FAULTY UNIT SELECTOR

As explained previously, making faulty unit selections requires that you reach a decision as to the possible equipment area(s) which could probably produce the trouble symptom and associated information. At this point in our six-step procedure, the trouble area will be restricted to a functional unit of the equipment. Thus, the functional block diagram is indispensable at this point.

Assume that you have found no reception as the trouble symptom for the transceiver whose functional block diagram is illustrated on fold-out page 2. Manipulation of the receiver volume and tuning controls has no effect upon the no reception condition. However, the power-on light and the dial lights of the receiver unit are all illuminated.

Out of the six functional units shown on fold-out page 2, only the power supply unit, the antenna assembly unit, and the receiver unit could possibly be at fault since these are the only units associated with signal reception.

Figure 10 shows the thought process involved in formulating a valid faulty unit selection. The answers to the questions you must ask will be obtained from your knowledge of how the equipment operates and/or from your use of the technical diagrams in the technical manual. Most of them should come from a study of the functional block diagram.

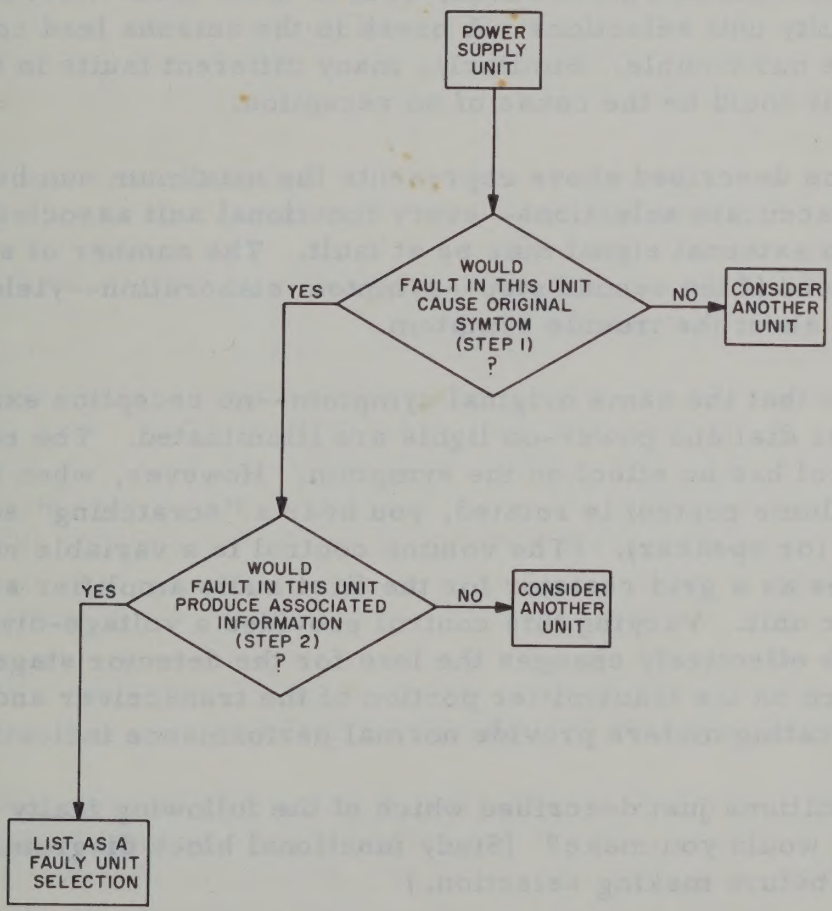
POWER SUPPLY UNIT
WOULD FAULT IN THIS UNIT CAUSE ORIGINAL SYMTOM (STEP 1) ?
YES
NO
CONSIDER ANOTHER UNIT
WOULD FAULT IN THIS UNIT PRODUCE ASSOCIATED INFORMATION (STEP 2) ?
YES
NO
CONSIDER ANOTHER UNIT
LIST AS A FAULY UNIT SELECTION

Figure 10. Considering Power Supply as a Faulty Unit Selection

First we consider the power supply unit and ask outsleves, "Would a failure or abnormal performance on the part of the power supply cause the original trouble symptom?" If the answer is "no," we can go on to consider another unit. If the answer is "yes," (as it is for the symptom given above), we ask ourselves, "Would a failure or abnormal performance on the part of the power supply produce the associated information obtained during symptom elaboration?" For this example the answer would be "yes," because the fact that the dial lights and power-on light are illuminated does not prove that the proper operating voltages are being produced. This is true because these lights are in the filament voltage circuit only. Therefore, we list the power supply unit as a faulty unit selection, and we also note that the portion of this unit responsible for providing filament voltages is probably okay.

Next we consider the antenna assembly unit and receiver unit (separately) in the same manner. For the no-reception symptom and associated information given above, both of these units must also be listed as faulty unit selections. A break in the antenna lead could easily cause our trouble. Similarly, many different faults in the receiver unit could be the cause of no reception.

The condition described above represents the maximum number of technically accurate selections--every functional unit associated with receiving an external signal may be at fault. The number of selections can be reduced if the second step--symptom elaboration--yields more information about the trouble symptom.

Assume now that the same original symptom--no reception exists. The receiver dial and power-on lights are illuminated. The receiver tuning control has no effect on the symptom. However, when the receiver volume control is rotated, you hear a "scratching" sound in the headset (or speaker). (The volume control is a variable resistor which serves as a grid resistor for the first audio amplifier stage in the receiver unit. Varying this control provides a voltage-divider action which effectively changes the load for the detector stage.) You also turn on the transmitter portion of the transceiver and find that all indicating meters provide normal performance indications.

For the conditions just described which of the following fualty unit selection(s) would you make? (Study functional block diagram, fold-out page 2, before making selection.)

SELECTIONS:

A. Power supply unit, antenna assembly unit, and receiver unit.

B. Receiver unit

C. Antenna assembly unit and receiver unit.

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A. Power supply unit, antenna assembly unit, and receiver unit.

No. If the power supply unit were failing or operating abnormally, the transmitter portion of the transceiver would show some sign of abnormal operation. The "scratch" from the receiver volume control rotation indicates that some signals within the receiver unit are being amplified and converted to sound. This further supports the idea that the power supply is okay.

Re-study pages 52 through 54 . Carefully consider the symptom information and make a more valid faulty unit selection.

B. Receiver unit.

No. This unit does not stand alone as a probable cause. The fact that their was a scratching sound in the receiver would indicate that at least part of the circuits (those following the volume control) are operating because they amplify the noise. There is no indication that a signal is being applied to the receiver. Therefore, the antenna unit cannot be eliminated.

C. Antenna assembly unit and receiving unit

Yes. This is the most valid list of selections in veiw of the symptom information and the signal paths and units in figure 9, fold-out page 2. The power supply can be eliminated because the transmitter is functioning properly and the "scratching" sound indicates good audio amplification in the receiver unit. This amplification would not be accomplished if the power supply were faulty. The presence of sound also will be considered later in our troubleshooting procedure. The receiver unit cannot be eliminated as a whole, and neither can the antenna assembly unit.

Again, using the transceiver as an example, let's assume different information and test your selection skill further.

The equipment operator reports that, while trying to send a scheduled report to another ship, he noticed that the tuning meter reading on the transmitter unit was very low. He also kept receiving a message from the other ship asking him why he was not transmitting.

You go to the radio shack and verify the symptom by trying to raise the other ship. You get no response. The tuning meter current is low, just as the operator described it. You try several other frequencies but raise no one.

The monitoring meter on the front panel of the modulator unit, shows the proper modulation of the r-f carrier signal. By tuning the receiver unit over its range, you find that you can hear other transmissions perfectly.

Which of the selections below lists the functional unit or units which are probably at fault?

SELECTIONS:

A. Pickup unit and transmitter unit.

B. Transmitter unit, power supply unit (high voltage portion), and antenna assembly unit.

C. Power supply unit (filament-voltage portion).

A. Pickup unit and transmitter unit.

No. A fault in either of these units could produce the original symptom --no transmission. However, during symptom elaboration you found that the r-f carrier was being modulated by the proper amount. There would be no modulation at all during normal "transmit" conditions if the pickup unit were not working.

You should have a basic knowledge of transmitters and receivers. Perhaps it would help you to read pages 50 and 51 again as a review.

B. Transmitter unit, power supply unit (high-voltage portion), and antenna assembly unit.

Good. Either of these units could be responsible for the original no-transmission symptom, as well as the associated information. The low tuning meter reading especially points to these units. Since the receiver and modulator are working properly, the power supply (filament and low-voltage portions) can be eliminated, because it does not fit the associated information. Neither does the pickup unit because during normal "transmit" operation there would be no modulation if this unit were not working. Although the transmitter unit is supplying the proper rf, its power stage(s) could be at fault.

C. Power supply unit (filament-voltage portion)

Absolutely not. The receiver unit works fine. The modulator unit shows proper modulation. The tuning meter shows some current, although this reading is below normal. Since the power supply feeds filament voltage to all units, this portion must certainly be functioning properly in order for the symptoms described to appear.

Radar Set Functional Block Diagram

Figure 11, fold-out page 3, represents the functional block diagram of a typical shipboard search radar set. It can be seen from the diagram that this particular set is composed of ten functional units, as represented by the blocks. The connecting lines between the blocks are labeled as to the type of signal or control which is passed between the functional unit.

In order to understand the meaning of the interconnections shown in figure 11, a knowledge of the basic concepts of a radar system is necessary. The term radar is derived from the words Radio Detection

And Ranging, which indicate the underlying principle of a radar system. If an object such as an aircraft, ship, or land mass is located in the path traveled by a transmitted radio wave, some of the radiated energy is reflected from the object back toward the transmitter. The wave travels at a constant speed so that if the time of travel can be measured, the distance between the transmission point and the reflecting surface can be determined.

The radar set in figure 11 is a pulse radar set, which transmits a short burst of r-f energy (pulse). Then the set quickly changes from a transmitter function to a receiver function so that any reflected energy can be picked up, and the reflections are presented on a cathode-ray tube properly calibrated to display range or other desired information. This transmit-receive cycle is repeated many times per second.

What is the purpose of a radar set such as the one described above?

SELECTIONS:

A. To detect and display information concerning the location of objects in the path of a transmitted radio wave.

B. To identify enemy targets within the range of the set designed capabilities. Either in the air or on the surface.

C. To receive the reflected radio waves that have been transmitted by the same radar equipment.

A. To detect and display information concerning the location of objects in the path of a transmitted radio wave.

Yes. These objects may be aircraft, ships, and land masses. The set can be used for target tracking and navigational purposes. There was no mention of provisions for identifying an enemy target, although this is possible. In providing the over-all operational function from which it receives its name, a radar must perform several electronic functions, such as transmission, reception, etc. These functions are provided by individual units, as shown in figure 11, fold-out page 3.

B. To identify enemy targets within the range of the set designed capabilities. Either in the air or on the surface.

No. This single action is not the total purpose of a radar set, although provisions described for identification is sometimes made. The pulse radar set described could be used to detect aircraft, land masses, or ships, as well as to indicate the range of these objects. Thus it can serve the purposes of target tracing and navigation.

C. To receive the reflected radio waves that have been transmitted by the same radar equipment.

This is not entirely correct. Receiving reflected radio waves is definitely an electronic function among all the necessary functions to accomplish the set's operational function, but it is only part of the function. The radar set may also be used for identification and range measurements

From the brief discussion given on the apron of the fold-out page, it is not expected that you will have a complete functional knowledge of a radar set. However, the discussion should acquaint you with the use of the functional diagram concept, as well as supply enough equipment knowledge for a few simple troubleshooting problems.

As a preliminary check of your knowledge of radar sets, what functional units are essential to the proper transmission of an r-f pulse? (Study figure 11, fold-out page 3, and the unit descriptions given on the fold-out apron before making your selection.)

SELECTIONS:

A. Radar set control, modulator, transmitter, duplexer, and antenna assembly.

B. Power supply, radar set control, modulator, adapter indicator, transmitter, duplexer, and antenna assembly.

C. Power supply, radar set control, modulator, transmitter, duplexer, and antenna assembly.

A. Radar set control, modulator, transmitter, duplexer, and antenna assembly.

No. Perhaps you were in too much of a hurry when you read pages 58 and 59. Review these pages and study the purpose of each block in figure 11, fold-out page 3. Careful evaluation of figure 11 will indicate that the power supply must be included for the other units to perform their function.

B. Power supply, radar set control, modulator, adapter indicator, transmitter, duplexer, and antenna assembly.

Wrong. The power supply, radar set control, modulator, transmitter, duplexer, and antenna assembly are necessary to transmit an r-f pulse. However, the adapter indicator unit serves as a junction box, amplifier, and impedance matching unit between the PPI unit and other information units in the set and is not essential to this operation.

C. Power supply, radar set control, modulator, transmitter, duplexer and antenna assembly.

You are correct. The interconnected operation of these six units is essential to transmitting the r-f pulse. The adapter indicator unit belongs in the group of units which accomplish the information interpretation function.

Let's try one more question, and then we'll get back to our primary concern--making faulty unit selections.

What units in figure 11, fold-out page 3, are essential to both transmission and reception functions?

SELECTIONS:

A. Power supply, radar set control, duplexer, and antenna assembly.

B. Power supply, radar set control, modulator, duplexer, and antenna assembly.

C. Power supply, radar set control, signal data converter, and antenna assembly.

A. Power supply, radar set control, duplexer, and antenna assembly.

Wrong. There is one important unit missing, although it may not be obvious that this unit is used for both functions. It is important that all operations of a radar have a common reference in respect to time. Some method of synchronizing the units is necessary. Notice that the line drawn down from the modulator supplies a trigger pulse to synchronize units in the set.

B. Power supply, radar set control, modulator, duplexer, and antenna assembly.

Very good. The power supply, radar set control, duplexer, and antenna assembly are obviously essential to both the transmit and receive functions. A little thought will also show that the modulator unit is essential to both functions since it provides the synchronizing pulses for nearly every unit in the set.

These two exercises have demonstrated the importance of the signal paths in a functional block diagram in relation to the blocks they connect. They have also provided practice in determining which units can be grouped together to perform certain electronic functions.

C. Power supply, radar set control, signal data converter, duplexer, and antenna assembly.

No. The power supply, radar set control, duplexer, and antenna assembly are essential to both transmission and reception. The signal data converter supplies ships heading information to the adapter indicator unit and receives information from the antenna but is not essential to the transmission and reception functions. There is an important unit missing that is necessary for both transmission and reception. The modulator is used to synchronize the units so that their functions will be performed in the proper sequence. Notice the trigger pulse connecting the modulator to the other units is used to synchronize the operations.

More selections

Now let's try to apply our selection technique to some trouble symptoms associated with radar sets. Refer to figure 11, fold-out 3.

For the first example, assume that the radar operator has reported that there are no signals on the screen of the plan position indicator. Elaboration of the symptom reveals the following:

1. The modulator and transmitter are operating properly.
2. There is a sweep trace rotating about the PPI screen, and the range marks are present.
3. The sweep trace is synchronized with antenna rotation.
4. Manipulation of receiver gain controls has no effect on the indicator presentation.

NOTE

The information above is gained by viewing the various meters and indicators and manipulating the various controls. To list all of the meters and controls at this point would be meaningless. The information given is related to the functions of each unit as described previously, and will enable you to follow the logic of faulty unit selection with your limited knowledge of radar sets.

Figure 12, page 66 shows the general thought process involved in selecting faulty units. It is the same procedure as illustrated before in more general terms. We select a functional unit and ask the question, "Could a fault in this unit produce the original trouble symptom?" If the answer is "no," we consider another unit. If the answer is "yes," we ask the question, "Could a fault in this unit produce the associated information obtained during symptom elaboration?" If the answer is "no," we must consider another unit. If the answer is "yes," we list this unit as a probable faulty function, and go on to consider another unit.

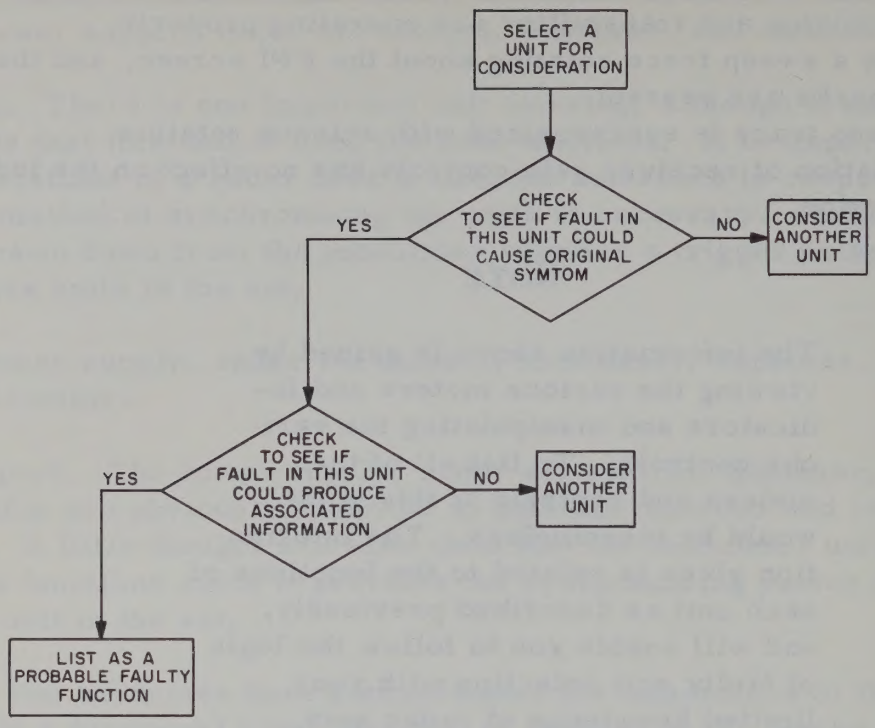

SELECT A UNIT FOR CONSIDERATION
CHECK TO SEE IF FAULT IN THIS UNIT COULD CAUSE ORIGINAL SYMTOM
YES
NO
CONSIDER ANOTHER UNIT
CHECK TO SEE IF FAULT IN THIS UNIT COULD PRODUCE ASSOCIATED INFORMATION
YES
NO
CONSIDER ANOTHER UNIT
LIST AS A PROBABLE FAULTY FUNCTION

Figure 12. Procedure for Identifying Probable Faulty Functions

For the symptom and information listed above, the modulator and transmitter units are automatically eliminated since they are performing properly. The power supply unit can be eliminated because the two units just named could not function properly if the power supply were at fault.

It should be noted here that some power supply units have separate sections supplying voltage to individual units. In this case, the sections associated with the modulator and transmitter could be okay while the others were not.

To make sure you understand the thought process involved in selecting a faulty function for evaluation, what would be involved when considering the duplexer unit?

SELECTIONS:

A. Select the duplexer unit for consideration, but since the transmitter is satisfactory, reject it and consider another unit.

B. Select the duplexer unit for consideration, and include it as a possible trouble because it may operate properly in transmit but not in receive.

C. The duplexer unit would not have to be considered since the trouble appears to be in the receiver because these controls are ineffective.

A. Select the duplexer unit for consideration, but since the transmitter is satisfactory, reject it and consider another unit.

No. You cannot be certain that the duplexer is not operating properly just because the transmitter and modulator are operating. It is possible that the duplexer is not coupling the signal to the receiver. It must be listed as a probable faulty unit.

B. Select the duplexer unit for consideration, and include it as a possible trouble because it may operate properly in transmit but not in receive.

Good. You are following the thought process as previously outlined. A unit can never be eliminated because it appears satisfactory in transmission if that unit is used in a different capacity for reception also. An electronic switching action takes place after transmission in order to couple the antenna to the receiver. It is possible that the signal is not being coupled to the receiver resulting in the controls being ineffective.

C. The duplexer unit would not have to be considered since the trouble appears to be in the receiver because these controls are ineffective.

Wrong. You are jumping to conclusions and not following the process outlined. Just because the receiver controls did not effect the display does not indicate the receiver is the faulty unit. It is possible that no signal is coupled to the receiver.

Further Considerations

The duplexer unit could be the cause of the "no-return" symptom if it were not switching to the receive function. This fault could also exist in the presence of the associated information. This unit is our first selection. It seems unlikely that the antenna assembly unit is at fault since the transmitter operated correctly, indicating a proper match between the transmitter and antenna. Since the same antenna and feed system is used with the receiver, we will eliminate this system. However, the receiver unit may be at fault, because the gain controls have effect on the presentation. We will list this as a selection. We now have two probable causes--the duplexer and the receiver units. The adapter indicator unit must also be listed as a selection since it lies directly in the main return path to the PPI. The PPI may also be at fault; although range markers and a sweep are available, circuitry associated with the main echo could be performing improperly.

The signal data converter would not produce the original symptom since it is a correlation unit not essential to the presentation of the return echo. Also, since the range markers are appearing on the screen, the signal data converter is performing properly. The radar set control unit is probably not at fault because the proper operation and performance of the transmitter, modulator, signal data converter, and antenna assembly units are dependent upon the control settings. Any improper control settings should have been discovered during the symptom elaboration step.

Our list of selections must therefore include the duplexer unit, receiver unit, adapter indicator unit, and plan position indicator unit.

Now, suppose that the radar set has two PPI units and that in addition to the four results of symptom elaboration obtained in the preceding problem there was a good display on one of the PPI's. Which of the probable faulty units above can now be eliminated?

SELECTIONS:

A. Receiver and duplexer units.

B. Receiver unit.

C. Receiver and PPI units.

A. Receiver and duplexer units.

Now you're on the right track. The duplexer and receiver units precede the PPI unit in the echo return path. Therefore, it seems logical that these units are operating properly if the echo information is being displayed on one of the PPI units. Since the PPI units are fed in parallel, it is entirely possible that one can operate while the other is malfunctioning.

B. Receiver unit.

No. You would be correct in eliminating the receiver since there is a satisfactory display on the second PPI unit. However, this would also indicate that the duplexer unit was operating satisfactory and could also be eliminated.

C. Receiver and PPI units.

Wrong. The PPI units are connected in parallel and receive their input from the adapter indicator unit. The lights in your house are connected in parallel so that if one burns out the others will still light. Since the PPI units are in parallel, one PPI unit could be faulty and the other units would still operate properly.

Additional Units

It is not likely that the adapter indicator unit is at fault because one of the PPI indicator units is performing properly. However, this unit cannot be entirely eliminated without further checks. Whenever a unit is used for a dual purpose, it must be considered as a possible cause of trouble until all phases are checked and proved to be satisfactory.

Employing the thought process previously outlined, each unit we have discussed so far has been considered and after determining if that particular unit could cause the symptom, the unit was either listed as a faulty function or eliminated as a source of trouble because a fault in this unit could not produce the associated information.

As another test of your "selecting ability," let's consider the pulse radar set again (refer to figure 11, fold-out page 3). The sweep on the PPI screen does not follow the rotation of the antenna. The modulator, transmitter, and receiver units all indicate perfect performance. The echos appear on the screen, but they cannot be related to antenna azimuth. Which units should be listed as probable selections?

SELECTIONS:

A. Antenna assembly and signal data converter units.

B. Antenna assembly, duplexer, and signal data converter units.

C. Antenna assembly, signal data converter, adapter indicator, and PPI units.

A. Antenna assembly and signal data converter units.

No. This answer is incomplete. The antenna could be at fault if it did not provide antenna positioning data to the signal data converter, and the signal data converter could be at fault since its function is to provide synchronizing signals between the antenna and ships head to insure accurate bearing information, but there are other units which may also result in the symptoms listed. The sweep circuitry of the PPI units may be faulty or the adapter indicator could be at fault.

B. Antenna assembly, duplexer, and signal data converter units.

No. The antenna assembly could result in these symptoms if it was not providing positioning data, and the signal data converter would also be included if it were not supplying the synchronizing data, but the duplexer unit cannot cuase the original trouble symptoms, because this unit has nothing to do with synchronizing the PPI sweep with antenna rotation.

C. Antenna assembly, signal data converter, adapter indicator, and PPI units.

Yes. These four units, all of which are in the sweep signal path, may be at fault. The antenna may not be providing position data, or the data link to the signal converter may be broken. The signal data link is essential to the synchronization process. Although the adapter indicator unit is passing the echo signals, it may not be passing a signal from the data converter to the PPI. The sweep circuitry of the PPI indicator could be at fault without interfering with the actual echo presentation.

By now you should recognize the improtance of eliminating as many units as possible during this step, as well as maintaining a list of valid units which may be at fault. The importance of the functional block diagram has also been demonstrated.

THE EXCEPTION TO THE RULE

There are some equipments which do not require a functional block diagram or a faulty unit selection process. These equipments are relatively simple devices and consist of only one functional unit.

Figure 13 shows the circuit for a multirange ohmmeter used to make resistance checks. It consists of a current indicating meter, a battery, and resistors of known value connected so that the unknown resistance can be compared with one of the known resistors. When the test leads are open, no current flows through the meter, and the meter is mechanically set to indicate an infinite resistance. When the test leads are shorted together, the meter is electrically adjusted to give a zero reading.

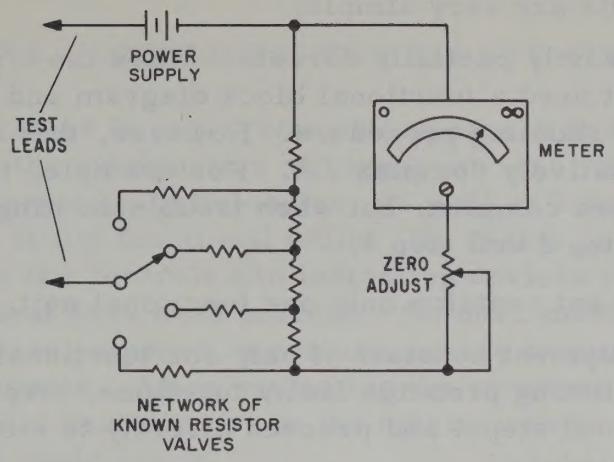


Figure 13. Simple Ohmmeter Circuit

When the test leads are placed across an unknown resistance, this resistance is in series with the battery and meter. The meter is both in series and in parallel with the known resistors. Thus the current through the meter will be some intermediate value between those values which produced zero reading and infinite reading. The actual value of this current will be determined by the ratio of the fixed and unknown resistors. An appropriately calibrated scale will allow the meter to indicate the value of the resistor being measured.

Equipments of this type represent almost an extreme in simplicity. For such equipments not only is a functional block diagram unnecessary, but, troubleshooting, step 3 (listing probably faulty indications) and step 4 (localizing the faulty function), can be omitted entirely from our six-step procedure.

Another example of an equipment consisting of a single functional unit is the TS-O oscilloscope, which is explained in the Volume II of this course. However, this equipment is not simple enough to be evaluated as quickly as the ohmmeter. Even though the TS-O is more complex, it is still possible to skip steps 3 and 4 and proceed to step 5 in our six-step procedure.

When is it possible to omit step 3 of our six-step troubleshooting procedure?

SELECTIONS:

A. When the circuits are very simple.

B. When the equipment contains only one functional unit.

C. When troubleshooting test equipment.

A. When the circuits are very simple.

No. This answer is only partially correct. When the circuits are very simple, you will not need a functional block diagram and you may omit step 3 in the troubleshooting procedure. However, this step may also be omitted for a relatively complex set. For example, the TS-O oscilloscope is much more complex, but when troubleshooting the TS-O you can still omit step 3 and step 4.

B. When an equipment contains only one functional unit.

True. When an equipment consists of only one functional unit, there will be no need for listing probable faulty functions, step 3. In this case we may also omit step 4 and proceed directly to step 5 in the troubleshooting procedure.

C. When troubleshooting test equipment.

No. Although many pieces of test equipment, such as the ohmmeter and oscilloscope previously mentioned, perform only one function, others such as some signal generators and multimeters perform more than one function. Only when troubleshooting those units that perform a single function, can step 3 be omitted.

Now you should have a very good idea of how to go about making a faulty unit selection--the decision as to which equipment functional units are probably causing the trouble. These selections must, of course, be logical and must be technically substantiated by the information you obtained during symptom elaboration, the relationships between signal paths and functional units, and your operational knowledge of the equipment.

One of the reasons for performing this step is to save time. This is accomplished by making technically accurate selections of units which could contain the malfunction. Doing this eliminates the necessity of making illogical checks of all units. However, it must be understood that each unit so selected is only a probable source of the trouble even though its selection is based on technically valid evidence. The next step explains a time-saving and logical method of locating the unit that is probably faulty.

Making technically accurate selections will allow you to accomplish the next step--localizing the faulty function--effectively and efficiently, just as understanding this lesson now allows you to begin Lesson No. 5.

STEP 4. LOCALIZING THE FAULTY FUNCTION

The first three steps in our systematic approach to troubleshooting have dealt with the examination of "apparent" and "not so apparent" equipment performance deficiencies, as well as a logical selection of the probable faulty functional units. Up to this point no test equipment other than the controls and indicating devices physically built into the equipment have been utilized. No dust covers or equipment drawers have been removed to provide access to any of the parts or internal adjustments. After evaluating the symptom information, you have made mental decisions as to the most probable areas in which the malfunction could occur.

Localizing the faulty function means that you will have to determine which of the functional units of the multi-unit equipment is actually at fault. This is accomplished by systematically checking each faulty functional unit selection until the actual faulty unit is found. If none of the functional units in your list of selections display improper performance, it will be necessary for you to back-track to step 3 and re-evaluate the symptom information, as well as obtain more information if possible. In some cases it may be necessary to return to step 2 and obtain additional symptom-elaboration data.

At this point--step 4 in the troubleshooting sequence--you will bring into play your factual equipment knowledge and your skill in testing procedures. The utilization of standard or specialized test instruments and the interpretation of the test data will be very important throughout this and the remaining troubleshooting steps.

Which of the following selections describes the primary intent of step 4--localizing the faulty function?

SELECTIONS:

A. The completion of this step puts me in a position to repair the fault.

B. By performing this step I will have isolated the trouble to the parts of one particular block on the equipment functional block diagram.

C. This finally allows me to use my knowledge of test equipment and procedures.

A. The completion of this step puts me in a position to repair the fault.

Absolutely not. Upon completing this step there will still be many parts possibly at fault. The isolation of the trouble down to a particular circuit and part--which is necessary before repairs can be made--does not come until later.

B. By performing this step I will have isolated the trouble to the parts of one particular block on the equipment functional block diagram.

Yes. There may still be many circuits and/or parts which could be causing the trouble, but this step will narrow the list of those to one functional unit.

C. This finally allows me to use my knowledge of test equipment and procedures.

No. This is not the primary intent of step 4. You will need a knowledge of test equipment and procedures in order to accomplish this step (and the steps to follow), but this particular step is primarily concerned with one accomplishment--determining which faulty functional unit selection is valid.

USEFUL TECHNICAL DIAGRAMS

In view of the working information (from steps 1, 2, and 3) and the primary intent of step 4, it should be apparent that the over-all equipment functional block diagram will be an essential reference for localizing the trouble to a functional unit. Since actual performance tests must be made, it will be necessary to know the normal performance characteristics of the equipment. For the purposes of step 4--localizing the faulty function--the test information required will be the input and output to each functional unit.

Generally, the input and output waveforms for each functional unit will be included on the over-all functional block diagram. However, when this is not the case, the information you will need can be found on the servicing block diagram for the appropriate functional unit. An example of this diagram is given in figure 14, fold-out page 4. This is the receiver unit for the transceiver set illustrated in functional block form on fold-out page 2.

Notice that each circuit or stage within the functional unit is represented by a separate block, which lists the code number for the tube(s) or transistor(s) in the circuit.

Main signal flow paths are indicated by heavy lines, and secondary signal paths are indicated by lighter-weight lines. At the input and output of each stage, the significant tube or semiconductor elements in the signal path are labeled with the following abbreviations:

TUBES	TRANSISTORS
P-plate	C-collector
G-grid	B-base
K-cathode	E-emitter

Waveforms for all inputs, outputs, and test points are illustrated near the points to which they refer. Operational controls and indicators, as well as internal adjustments, are given.

As mentioned previously, the input and output test points and waveforms for the functional unit itself are the only data we are interested in at the moment. These can be found by determining the input and output circuits of the unit. For example, in figure 14, the input circuit for the receiver unit is the r-f amplifier, V1. (The grid, pin 3, is the input injection point.) The electrical output for this unit can be obtained at terminal 5 of the output transformer, T10. The input circuit receives a signal from another unit, and the output circuit supplies a signal to another unit.

There are certain exceptions to this rule; for example, the oscillator, V11 in figure 14, has not input but it does provide an output.

In order to test your ability to use a functional unit servicing block diagram to locate unit input and output points, consider the servicing block diagram in figure 15, fold-out page 4, which is the modulator unit for the transceiver illustrated in figure 9, fold-out page 2. What are the input and output test points for this unit?

SELECTIONS:

A. The unit has one input--at the grid (pin 3) of V1, and one output--at terminal 5 of T4, the modulation transformer.

B. The unit has one input--at the grid (pin 3) of V1, and two outputs--one at the plate (pin 5) of each audio amplifier.

C. The unit has one input--at the grid (pin 3) of V1, and two outputs--one at terminal 5 of T4, the modulation transformer, and the other at the cathode (pin 4) of the modulation monitoring circuit.

A. The unit has one input--at the grid (pin 3) of V1, and one output--at terminal 5 of T4, the modulation transformer.

Yes. There is one signal path through the modulator unit. The grid of V1 receives a signal from the pick-up unit, and the modulation transformer, T4, supplies a signal to the transmitter unit. The modulation monitoring circuit is contained within the modulator unit, and is not classified as an output of this unit.

B. The unit has one input--at the grid (pin 3) of V1, and two outputs--one at the plate (pin 5) of each audio amplifier.

No. According to our discussion on the use of a servicing block diagram, to determine unit input and output points, we must first determine the first circuit in the unit's signal path(s) and the final circuit in the path(s). The audio power amplifiers are not the last circuits in the a-f signal path through the modulator unit. In general, therefore, the input point is the tube, transistor, or circuit element that receives the output of the preceding unit, and the output point is the tube, transistor, or circuit element that supplies the output to the next unit.

No. According to our discussion on the use of a servicing block diagram, to determine the first circuit in the unit's signal path(s) and the final circuit in the path(s). The audio power amplifiers are not the last circuits in the a-f signal path through the modulator unit. In general, therefore, the input point is the tube, transistor, or circuit element that receives the output of the preceding unit, and the output point is the tube, transistor, or circuit element that supplies the output to the next unit.

C. The unit has one input--at the grid (pin 3) of V1, and two outputs--one at terminal 5 of T4, the modulation transformer, and the other at the cathode (pin 4) of the modulation monitoring circuit.

No. The modulation monitoring circuit is a part of the modulation unit, but has nothing to do with applying the a-f signal to the transmitter unit. Thus, it is not classified as an output for the modulation unit. In localizing the trouble to a functional unit, remember that we are concerned only with those circuits receiving signals from another unit and supplying signals to another unit.

Wiring Diagrams

Another type of diagram which you will find useful at this point in the troubleshooting procedure is the wiring diagram. This diagram will aid you in finding the most accessible point at which to perform an actual test. An example appears on fold-out page 55-56, figure 20, in the TS-O manual Volume 3 of this course.

The wiring diagrams show the interconnecting cables between separated units. The cable plugs and sockets are coded and the prong connections are numbered as a further aid. By referring to this diagram you will be able to trace a signal, control, or power line from one unit to another. You will also be able to determine whether the removal of a cable for testing purposes will remove any necessary operating or control voltages.

Every technical diagram we have discussed has its own purpose and place at this point in our troubleshooting procedure. Experience with the interrelated use of all diagrams will help you in developing speed and efficiency as a troubleshooter.

Which of the following selections describes the primary purpose of the wiring diagram.

SELECTIONS:

A. To aid in tracing the wiring between various circuits within the unit enclosure.

B. To provide voltage and waveform information not found on the servicing block diagrams.

C. To aid in tracing the signal through the equipment.

A. To aid in tracing the wiring between various circuits within the unit enclosure.

Yes. The cabling and wiring diagrams will show how the various circuits, stages, sections, and units are connected together. The information may also be helpful in finding the best place to connect your test equipment in order to obtain the voltages and waveforms shown on some diagrams.

B. To provide voltage and waveform information not found on the servicing block diagram.

No. Nothing was said about this sort of test information being given on wiring and cabling diagrams. This information is provided on the servicing block diagram and, occasionally, on the equipment functional block diagram.

C. To aid in tracing the signal through the equipment.

Absolutely not. So for you have been introduced to three types of technical diagrams. Each has a specific use, as described at the points where they were introduced and explained. As a brief review:

1. The over-all equipment functional block diagram represents all functional units in an equipment, with the signal paths between them. This diagram is your primary technical reference for step 3 (faulty unit selection) and step 4 (faulty unit location).
2. Servicing block diagrams are block diagrams of all the circuits and stages in a functional unit. The control and indicating device connections are included. All major and secondary signal paths are shown, along with the pin connections to each circuit or stage. In step 4 of our procedure, this diagram is used to find the test points and test waveforms associated with the input and output of each functional unit.
3. The wiring diagram shows how the wiring runs between functional units.

Some of these diagrams will find further uses as we progress through our six-step procedure. These will be explained as they are needed.

TESTING A FAULTY FUNCTIONAL UNIT SELECTION

The intent of the fourth step is to determine the functional unit of an electronic equipment which is responsible for the indicated failure. The selection of any unit as the probable cause should always be based upon equipment knowledge and basic electronic pricniples. In the previous lesson, step 3, it was pointed out that there may be only a few possibilities or there may be many possibilities for faulty functional unit selections. The number of selections is entirely dependent upon the type of equipment and the information gathered in steps 1 and 2 of the troubleshooting procedure.

The use of a logical approach is choosing the first faulty functional unit selection to be tested is of prime importance. In Lesson No. 1 of this text the need for a logical approach was pointed out. The need for logic was again stressed in Lesson No. 3. When learning the operation of an equipment or when troubleshooting an equipment, this continuous use of logic must be followed. A logical approach is dependent upon equipment knowledge and an understanding of the situation.

Factors to Consider

The simultaneous elimination of several functional units as the cause of the trouble symptom should be an important factor in deciding which faulty unit selection to test first. This requires an examination of the functional block diagram to see whether satisfactory test results from any one of the selections could also eliminate other units listed as probable causes.

Test point accessibility is also an important factor affecting the technician's logic in choosing a faulty functional unit selection for further examination. A test point, as described in some instruction books, is a special jack located at some accessible spot on the equipment, such as the front panel or chassis. The jack is electrically connected (directly or my means of a switch) to some important operating potential or signal voltage. Actually, any point where wires join or where components are connected can serve as a test point.

As an example, consider the pulse radar set introduced in the previous lesson. The radar operator has reported that there are no return indications on the screen of the PPI. Elaboration reveals that the modulator and transmitter are operating properly and that there is a sweep trace on the PPI screen, rotating in synchronization with the

(Blank)

antenna. The range marks are also present on the PPI screen. We decided in the previous lesson that the faulty unit selections must include the duplexer unit, receiver unit, adapter indicator unit, and PPI unit.

Consulting figure 11, fold-out page 3, will show that a satisfactory test at any functional unit following the duplexer unit in the echo pulse (video signal) path will eliminate two or more units as probable causes. For instance, if the output from the adapter indicator unit is found to be satisfactory, then the receiver unit, duplexer unit, and adapter indicator unit can be eliminated as faulty units.

Which of the faulty functional units selections for the pulse radar set example (figure 11, fold-out page 3) is the most logical first choice to test in view of eliminating more than one unit simultaneously, and locating the faulty unit with a minimum number of possible tests?

SELECTIONS:

A. The receiver unit.

B. The adapter indicator unit.

C. PPI unit.

A. The receiver unit.

Yes. As described in the example, a satisfactory output from this unit will eliminate both the receiver unit and the duplexer unit. It will allow the faulty unit to be selected in a maximum of two operations. That is, if the receiver output is unsatisfactory, the technician proceeds to the output of the duplexer and makes his second check. If this too is unsatisfactory, he has isolated the fault to the duplexer unit; if not, the fault is in the receiver unit. If the output of the receiver is satisfactory, the technician proceeds to the output of the adapter indicator. If this too is unsatisfactory, the trouble is isolated to the adapter indicator; if not, the fault is in the PPI unit. Thus, the technician performs only two tests--one at the output of the receiver unit, the center of the chain, and the other at the output of either the duplexer or the adapter indicator.

B. The adapter indicator unit.

No. If the test is unsatisfactory (that is, if the output of the adapter indicator is not right), then you must move to the receiver output, and if that too is unsatisfactory you must go to the output of the duplexer. The point is this--under the worst conditions you will have to make three tests, whereas with selection A, the receiver unit, you will make, at the most, only two tests. Of course, you may be fortunate and find that the output of the adapter indicator is satisfactory; thus the PPI is at fault and you've solved the problem in one test.

You should note, however, that the most logical choice is the one that turns up the answer with the least number of possible tests.

C. PPI unit.

No. If the output of the PPI unit was unsatisfactory, a check would have to be made at the output of the adapter indicator, another at the output of the receiver and again at the output of the duplexer unit. It may require 4 checks to isolate the faulty unit. Of course you may be lucky and locate the faulty unit on the first or second choice, but logic, not luck provides the most rapid means for locating the trouble.

You should note that if the most logical choice, the output of the receiver were checked, a maximum of two checks would locate the faulty unit. A logical choice will turn up the faulty unit with the least number of checks.

Another factor to consider is past expereience and history of repeated failures. Past experience with similar equipment and related trouble symptoms, as well as the probability of unit failure based upon records of repeated failures, should have some bearing upon the choice oi a first test point. However, the selection should be based mainly upon a logical conclusion formed from data obtained in previous steps, without undue emphasis upon past experience and history of the equipment.

In summary, then, the factors to be considered in selecting the first test point, listed in their usual order of importance, are as follows:

1. The functional unit that will give the best information for simultaneously eliminating other units, based upon the data obtained in steps 1, 2, and 3 of our procedure, provided that a certain unit is not obviously the cause.
2. Accessibility of test points--for example, a test point might be avoided as a first choice merely because the equipment must be disassembled to obtain access to this test point.
3. Past experience and history of repeated failures, provided that this factor is carefully weighed in the light of data obtained in steps 1. 2, and 3.

Now let's try our hand again at the selection of a first test point; consider a transceiver with a "no reception" trouble symptom. There is no audible signal from the receiver, and there is no effect produced by manipulating the volume controls. In a previous lesson we decided that either the power supply, receiver unit, or antenna assembly could be at fault. Suppose that all test points are equally accessible and that a previous history of failures (as indicated on the equipment history card) shows that the local oscillator tube of the receiver has been replaced on many occasions. The choice of the first test point should be made by reference to figure 9, fold-out page 2. Based upon the data given, which test point is most logically the first choice?

SELECTIONS:

A. The receiver unit output.

B. The receiver unit input.

C. The power supply output.

A. The receiver unit output.

No. Apparently you have not studied the facts. The receiver is not providing an output; therefore, one of the symptoms is that the receiver output is not present, and no test at this point is required.

B. The receiver unit input.

No. The receiver has been described as dead (that is, no audible sound at its output); you should be more inclined toward another choice. It is likely that an input is present and that the "no output symptom" is due to something within the receiver or its power supply.

C. The power supply output.

Yes. The fact that the receiver is completely inoperative can be considered a good reason to logically check the output of the power supply first, rather than the input to the receiver. Of course, the receiver input might not be present, but at least some output noise or indication that the volume control affects the output should be apparent. You may ask what about the previous history of tube failures? Why wasn't that considered? The answer is that it dosen't make sense because the receiver output is not discernible, and the failure of the local oscillator would not ordinarily eliminate all sound from the speaker; therefore, this piece of past history has been bypassed. If, however, the receiver output is merely noise, and no stations can be received there is a greater possibility that the local oscillator is inoperative. The input to the receiver should be checked to see whether stations are being received.

In this case you have three possible choices in making a logical selection for the first test point. Because the receiver output was not audible and since the volume control had no effect upon the output, you choose the power supply as the best point to test. Of course, the fact that the receiver output was not present narrows your choices to: (1) the power supply and (2) the receiver input. In this case the power supply output was chosen because the receiver was dead, and the past history information was not used since it was not directly applicable. Suppose, however, that the receiver output consists of a noise background and that the output can be adjusted with the volume control. Also suppose that a previous history of local oscillator failure has been found. What choice of a first test point would be made under these circumstances? Refer to figure 9, fold-out page 2.

SELECTIONS:

A. The receiver input.

B. The receiver output.

C. The power supply output.

A. The receiver input.

Right. The fact that the output noise was adjustable indicates that the audio stages have power supply voltages, and even if these voltages are not present in the other receiver circuits, the fault still may be a component in the receiver rather than in the power supply. Thus, it is safe to assume that the power supply output is satisfactory. This fact, plus the history of previous local oscillator failures, leads you to conclude, tentatively, that the receiver is probably faulty. If a check reveals that a signal is present at the receiver input, you have even more reason to believe that the local oscillator tube has failed. Although this conclusion is not definite, the check has established that one receiver input is present, and a check of the power supply output will now isolate the trouble to the receiver unit. If the first check revealed that no receiver input signal was present, you would have the trouble isolated to the antenna unit.

B. The receiver output.

No. The fact that there is a noise coming from the speaker and that this noise can be adjusted, would eliminate this check. The receiver may be at fault but checking the output would not logically assist you in locating the trouble.

C. The power supply output.

No. The fact that the volume control will adjust the noise level indicates that at least the audio stages, and perhaps even the i-f stages, are operating properly. Since these circuits require voltages from the power supply, it is safe to assume that at least part of the power supply output is satisfactory. It is possible, of course, that only the voltages to the other receiver stages are not being obtained from the power supply; however, the power supply output is not the most logical choice.

TEST RESULTS AND CONCLUSIONS

Now that you have mastered the process of choosing the first faulty functional unit selection to test in your attempt to locate the faulty functional unit, you might ask "Where do I go from here?" The answer, of course, depends upon the results of your first test; for example, the solution to the previous problem indicated that further tests are usually necessary in order to prove your point.

There can be only two results--a satisfactory indication or an unsatisfactory indication. The latter may be in the form of no indication or a degraded indication. In any event, the result obtained should lead you to the next logical test.

Let's use the pulse radar set as an example again. The symptom is "no target indications on the PPI screen." The modulator and transmitter are functioning properly. The sweep is present and is synchronized with the antenna rotation. The range marks are present. We have already decided that out of the four faulty functional functional unit selections (the duplexer, receiver, adapter indicator, and PPI units) the most logical place to perform the first test is at the output of the receiver. Therefore, we should proceed as indicated in the discussion below.

First, let's assume that the output of the receiver is satisfactory. Figure 16 will give you a pictorial view of the thought process we are going to discuss. You may also want to consult figure 11, fold-out page 3. The satisfactory receiver output eliminates the receiver and the duplexer units. Thus the faulty unit must be the adapter indicator unit or the PPI.

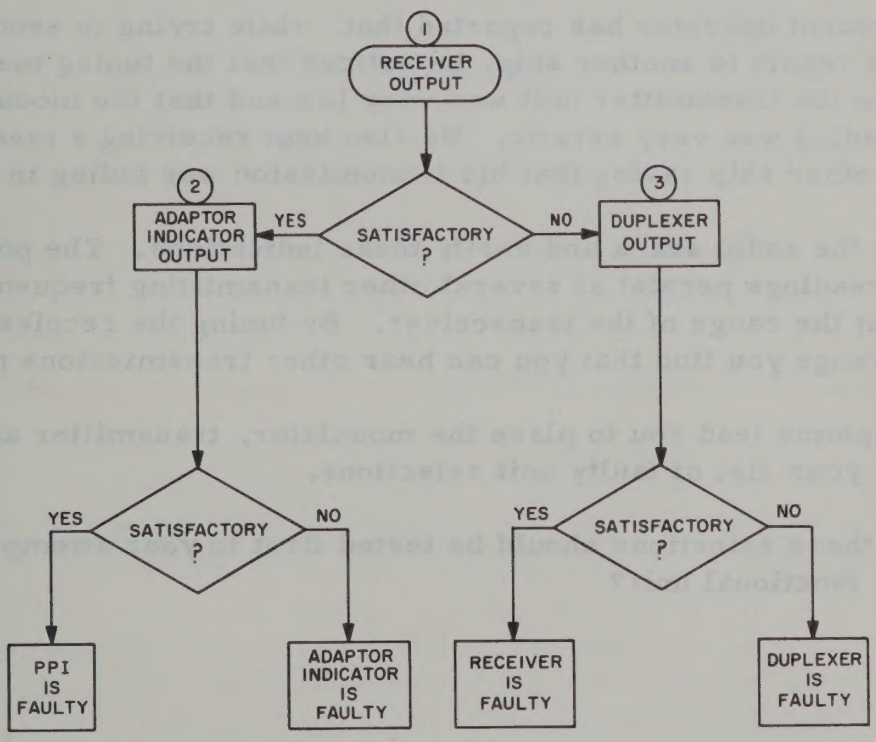


Figure 16. Test Sequence for Example Problem

A second test is required to isolate the faulty functional unit; this test would be made at the output of the adapter indicator unit. If the test at the output of the adapter unit is satisfactory, the faulty unit is the PPI unit. If the test at this point is unsatisfactory, the faulty unit is the adapter indicator unit. In either case, two tests will isolate the faulty unit.

The second test depends, as you can see, upon the results of the first test, but the idea is that the process should be a logical one, and (in this example) you should perform only two tests. If the output of the receiver unit is unsatisfactory, then you would test the output of the duplexer to determine whether a satisfactory output appears at this point. Again, depending upon the results of this test, the faulty unit would be isolated. An unsatisfactory test at the duplexer output would indicate that the duplexer is faulty, whereas a satisfactory test at this point would indicate that the receiver is faulty.

Now we have seen how a satisfactory or unsatisfactory result at a test point can help us decide which point to test next. Let's use the transceiver as our faulty equipment. The functional block diagram is on figure 9, fold-out page 2.

The equipment operator has reported that, while trying to send a scheduled report to another ship, he noticed that the tuning meter reading on the transmitter unit was very low and that the modulation meter reading was very erratic. He also kept receiving a message from the other ship saying that his transmission was fading in and out.

You go to the radio shack and verify these indications. The poor transmission readings persist at several other transmitting frequencies throughout the range of the transceiver. By tuning the receiver unit over its range you find that you can hear other transmissions perfectly.

Such symptoms lead you to place the modulator, transmitter and power supply on your list of faulty unit selections.

Which of these selections should be tested first in your attempt to locate the faulty functional unit?

SELECTIONS:

A. The modulator output.

B. The power supply outputs.

C. The transmitter output.

A. The modulator output.

No. This is not the ideal point to test first. A satisfactory result at this point would eliminate only the modulator unit; an unsatisfactory result would eliminate only the transmitter, since this result could still be produced by a faulty power supply. To consider the elimination of only one unit at a time will prove wasteful in the general trouble-shooting project. In choosing your first test point, remember that unless there is some information which points to a specific unit, you should always aim for the elimination of several functional units simultaneously.

B. The power supply outputs.

Yes. The power supply provides voltages to both the other functional units. Poor operation of both the modulator and the transmitter points to the possibility of a faulty power supply. The power supply is also a logical choice from the standpoint of simultaneous elimination.

The fact that the receiver was operating properly should not have caused you to assume the power supply was satisfactory. Remember that the power supply is capable of providing two or three different voltages. The voltage supplied the receiver may be satisfactory, while the high voltage to the modulator and transmitter may be faulty.

C. The transmitter output.

Wrong. There is no indication that should lead you to check the transmitter output as your first check. Symptoms indicate that both the transmitter and modulator are not performing satisfactory. This should lead you to suspect a unit common to both; or your first check should be the power supply outputs.

Each time a check is made it will be necessary to repeat the thought process again to determine where the next check should be made. By utilizing such a thought process, a logical approach to troubleshooting can be achieved and the faulty unit isolated with the least number of checks.

In the event that the power supply output voltages are satisfactory, which point should be tested next?

SELECTIONS:

A. The transmitter output.

B. The modulator output.

C. Either the transmitter or the modulator.

A. The transmitter output.

No. Selecting this as the next test point would provide no information we do not already have. We know that the modulation meter is reading erratically and that the tuning meter reads low; therefore, we would naturally expect an abnormal transmitter output. Furthermore, this abnormal output could still be provided by either the modulator or the transmitter.

B. The modulator output.

Certainly. A study of the information on fold-out page 2 should lead us to realize that an erratic modulation meter reading and a low tuning meter reading are definite indications of an abnormal transmitter output. A reading at the modulator output will isolate the faulty functional unit. If the reading is satisfactory, the transmitter is at fault; if the reading is unsatisfactory, the modulator is at fault.

C. Either the transmitter or the modulator.

Definitely not. All previous information has pointed to the fact that each test should eliminate as many units as possible. A check at the transmitter output would provide little if any information not already available. The fact that the modulation meter is reading erratically and the low reading on the tuning meter, along with your knowledge that the transmitters output is dependent on the modulator, should lead you to check the modulator first. A single check of this unit would isolate the faulty unit. If the check was satisfactory the transmitter would be at fault, if unsatisfactory, the modulator would be at fault.

Further Practice in Localizing the Faulty Function

The radio operator has reported a symptom of "weak reception" from a transceiver set such as the one pictured by the functional block diagram in figure 9 fold-out page 2. You have verified the symptom and, while performing symptom elaboration, you have found that the receiver tuning control permits you to "tune-in" all the usual transmissions, but they are weak. The receiver volume control permits you to vary the volume over a full range of sound level, but at its maximum position the sound level is still below that normally produced. As an additional test you switch the transceiver to the "transmit" function and note that the reading on the modulation meter is normal but the reading on the transmitter indicator is lower than normal.

This information permits you to place the power supply unit and the antenna assembly unit on the list of faulty unit selections, since either of these units could affect both transmission and reception. Which of these functional units should be checked first?

SELECTIONS:

A. Power supply unit.

B. Anetnna assembly unit.

A. The power supply unit.

No. There is no information given that makes the choice of the power supply unit more desirable than the antenna assembly unit. Since the power supply is common to the transmitter and the receiver, and both of these units are misbehaving, it is true that the power supply is a possible faulty unit. However, remember that the modulation meter reading was normal, and the power supply unit is common to all units.

B. Antenna assembly unit.

Yes. The antenna assembly is a more logical selection than the power supply unit, primarily because the modulator was operating satisfactorily. However, there may be a practical problem to consider here. Although the antenna assembly unit is a logical first choice, it may be advisable to test the power supply unit first if the antenna assembly unit is not readily accessible or if tests on this unit are more difficult to make.

Difficulty in making the test may influence your choice of which unit to check first. If a test would eliminate a number of units and would be the most logical first choice, this test may be deferred if it involved removing panels or plates in order to get to the test point.

Analyzing the tests

Once the units have been isolated, what happens if the last check doesn't pinpoint the faulty unit? In this case you have either made an error in making one of your checks or the results of the check was misunderstood, leading you down the wrong path. This points out the importance of writing down your results. If you have the information written down, it is not difficult to look back and determine where you went astray.

You will recall we have isolated our trouble to the antenna assembly or the power supply unit. Suppose that both units check out satisfactorily. What conclusion should you reach at this point?

SELECTIONS:

A. One of these functional units has to be at fault.

B. I should return to the previous steps and re-evaluate my information and selections.

C. I don't know.

A. One of these functional units has to be at fault.

No. Although your choices may appear to have been made in a logical manner, it may be possible that none of the units are at fault. This could be caused by misinterpretation of information obtained or the lack of information that caused you to make a wrong decision and lead you down the wrong path.

B. I should return to the previous steps and re-evaluate my information and selections.

Good. In making these selections, you have overlooked some data in the symptom elaboration or you may have missed a possible faulty function. The only way to determine this is to re-evaluate the information that you have obtained to determine where you went astray.

C. I don't know.

Come now. In Lesson No. 1 we introduced the idea that you might have to take a return path to a previous step in order to re-evaluate the information and the steps you have taken.

Further Elaboration

If a final check shows the suspected units to be satisfactory, it will be necessary to re-evaluate the information obtained from the previous checks. The question now is how far back should you go?

You could ignore all the information and start over at the beginning with step 1, Symptom Recognition; however, this should not be necessary because the fact that there is a trouble should have been pretty will established when the trouble was first reported. Returning to step 2, Symptom Elaboration, would allow you to re-evaluate the meter readings or other indications that were present when the operating controls were manipulated. A return to step 3, Listing of Probable Faulty Functions would permit a review of the list of faulty units previously prepared to insure that a possible faulty unit was not overlooked.

Now that we have reviewed the previous steps, assume that when you made the previous checks of the transceiver that neither the antenna assembly check or the power supply check indicate trouble. Would you return to step 1, 2, or 3 for re-evaluation?

SELECTIONS:

A. Step 1.

B. Step 2.

C. Step 3.

A. Step 1.

No. The symptom hasn't changed and the elaboration from step 2 should have provided sufficient information to aid you in selecting a list of faulty functions. Until you have assured yourself that steps 2 and 3 have been correctly interpreted, there is no need to go back this far.

B. Step 2.

No. The possibility of missing a faulty functional unit selection is present, and should be checked first. There is no evidence at this time that the symptom elaboration step was not performed correctly.

C. Step 3.

Yes. You should first assure yourself that from your knowledge of the symptoms and the symptom elaboration, you have chosen all possible faulty functional units. If you cannot logically include other functional units in your list of selections, you should drop back to step 2 and see whether in symptom elaboration you have overlooked something that could cause you to reconsider your faulty functional unit selections. In other words, you should retrace your steps one by one rather than jumping over the whole group back to the starting point.

In the example given, you were concerned with low output in the transmitter and also poor reception of signals. Therefore, to apply the principle stated above, you should first go back to step 3 and consider whether you have made all choices possible for this problem. You may decide that the transmitter and receiver could be included in the list of selections if there is a good chance that there are two separate troubles--namely, the transmitter has a fault and so does the receiver. You ignored this possibility when you chose only the units common to both. After checking all units, suppose that no unit is found which has an abnormal output; then you should go back to step 2 and see whether something was overlooked in symptom elaboration.

TROUBLE VERIFICATION

Having isolated the trouble to the actual functional unit at fault, it is now necessary to reconsider whether a fault in this unit could logically produce the trouble symptom and fits the associated information obtained during symptom elaboration. To do this you will have to use the functional block diagram again.

In order to locate the faulty functional unit, we proceded from symptom information to actual location. To verify the located functional unit we

proceeded from symptom information to actual location. To verify the located functional unit we will proceed in the reverse direction. We will ask the question, "What trouble symptoms would this faulty unit produce?" Thus, equipment knowledge is very important.

If you will refer to figure 9, fold-out page 2, you will be able to follow the logic in the example to be presented.

Assume that the fault lies in the antenna assembly unit. It does not automatically switch over to the "receiver function" as it should. What trouble symptom would this failure produce?

First of all, we know that the symptom should occur only in the units associated with the receiver function. This would include the receiver unit. The modulator and transmitter units should be performing properly. The receiver should provide all normal responses, noise in the speaker and the ability to vary the noise with the operating controls. However, no signal would be present.

If the original trouble symptom and the associated data collected during symptom elaboration fit the above expectations, we have verified the faulty functional unit.

Assume you have tested the output.of the sound pickup unit and found that there is no signal. What symptom and associated information would result from this absence of signal?

SELECTIONS:

A. There would be no sound output from the receiver unit.

B. The transmitted signal would be a constant-amplitude r-f signal, and the receiver unit would function normally.

C. No r-f signal (carrier or AM) would be transmitted, but the receiver unit would function normally.

A. There would be no sound output from the receiver unit.

Absolutely wrong. The signal from the sound pickup unit has nothing to do with the sound output from the receiver unit. The output of the sound pickup unit is associated with the transmission function of the transceiver set only.

B. The transmitted signal would be a constant-amplitude r-f signal, and the receiver unit would function normally.

Yes. The a-f signal from the sound pickup unit is eventually used to amplitude-modulate an r-f carrier signal. Its absence means that no modulation will occur. Yet, the carrier signal, which is produced in the transmitter unit, will still be generated and will be radiated as a constant-amplitude (zero-modulation) r-f signal. The receiver unit is not associated with the a-f signal from the sound pickup unit, and would, therefore, operate normally.

C. No r-f signal (carrier or AM) would be transmitted, but the receiver unit would function normally.

No. The output of the sound pickup unit would affect only the amplitude modulation of the r-f carrier signal. The carrier is produced in the transmitter section, and would still be produced despite the absence of an a-f signal.

Step 4--localizing the faulty function--has been concerned with the testing of an equipment on a limited basis; that is, it has considered only those tests that are necessary to isolate a faulty functional unit. A logical application of equipment knowledge and symptom analysis, coupled with the three factors--simultaneous elimination of several functional units, test point accessibility, and past experience and history of repeated failures, enabled you to take the list of faulty functional unit selections made in step 3 and pick the most logical one for the first test. This same logic was then applied to the systematic selection of all subsequent test points. At each point, a new bit of information enabled you to narrow the trouble area until the faulty functional unit was located.

The completion of this step as presented in this text should leave no doubt as to which functional unit is at fault. However, as a final check of your work, you have been made aware of the necessity to verify the isolated faulty functional unit by "back-tracking" and matching the theoretical trouble symptoms with those actually present.

You may now begin Lesson 6, which discusses step 5--localizing trouble to the circuit.

STEP 5. LOCALIZING TROUBLE TO THE CIRCUIT

Steps 1 and 2--symptom recognition and symptom elaboration--of the six-step troubleshooting procedure provide you with initial diagnostic information. This information, ascertained from the operation of controls on the equipment, provides visual indications, such as meter readings or scope presentations, so that the effects of the trouble can be further evaluated. Step 3--listing of probable faulty functions--applies this information and your equipment knowledge so that you can select the functional units, in a multi-unit set, which are most probably causing the trouble. Actual tests were performed in step 4--localizing the faulty function--so that you could isolate the faulty portion of the equipment.

Radar and communication equipment normally consist of multi-unit sets and each step in the logical process must be considered in the proper sequence. However, some equipment such as ohmmeters or the TSO oscilloscope, consist of a single functional unit. In this case steps 3 and 4 can be eliminated. After completing step 2, you would proceed directly to step 5 - localizing trouble to the circuit.

In step 5--localizing trouble to the circuit--you will do rather extensive testing in order to isolate the trouble to a specific circuit within the faulty functional unit. To accomplish this, you will first be concerned with isolating a group of circuits within a functional unit, arranged according to a common electronic sub-function. Once the faulty circuit group has been located, you can perform the tests which will isolate the faulty circuit(s).

This procedure adheres to the same reasoning we have used throughout our six-step troubleshooting procedure--the continous "narrowing down" of the trouble area by making logical decisions and performing logical tests. Such a process, as mentioned in Lesson No. 4, reduces the number of tests which must be performed. This reduction of tests not only saves time but also minimizes the possibility of error.

To gain a better understanding of this successive functional division, refer to figure 17. First there is the equipment or set which is designed to perform an over-all operational function. We see that steps 1 and 2 of our troubleshooting procedure are associated with this functional classification. The set is then divided into functional units, each designed to perform a major electronic function vital to the over-all operational function. Steps 3 and 4 are associated with this category. When there is only one functional unit, steps 3 and 4 are skipped.

The next division--the circuit group--is a convenient subdivision of the functional unit. The circuits and stages in the circuit group perform an electronic sub-function vital to the task assigned to the functional units. Our first concern in step 5 is to determine which of these groups are at fault. After this is done, we can go deeper into the equipment to isolate the final equipment division--the individual circuit.

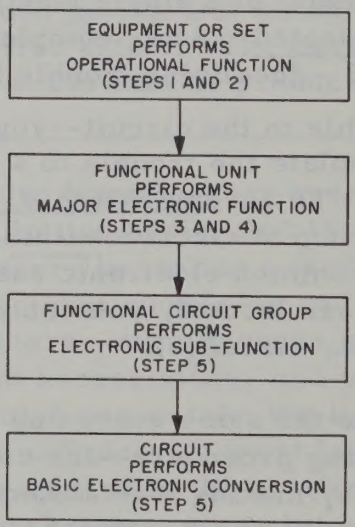


Figure 17. Functional Divisions of Equipment

Which of the selections below best describes step 5--localizing trouble to the circuit?

SELECTIONS:

A. It allows me to isolate the trouble to a sub-function.

B. It allows me to determine which circuit in the electronic equipment contains the faulty part.

C. It permits me to find the faulty parts and perform the repair which will put the equipment back in operation.

A. It allows me to isolate the trouble to a sub-function.

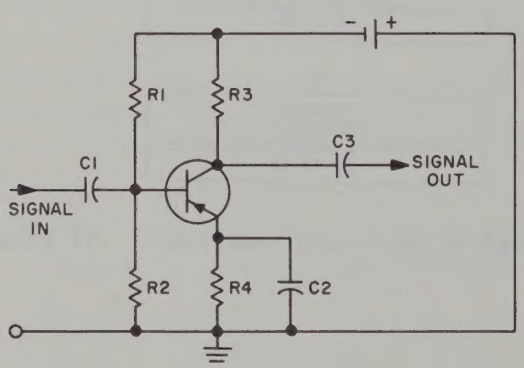
Not quite. Locating the defective sub-function is only part of step 5. Remember that a sub-function is a circuit group which is a division of a functional unit; step 5 does not end at this point. Therefore, you should read page 161 again and make another selection.

B. It allows me to determine which circuit in the electronic equipment contains the faulty part.

Yes. The completion of this step brings you closer to the point where you will be able to repair the equipment and return it to service.

C. It permits me to find the faulty part(s) and perform the repairs which will put the equipment back in operation.

No. The last functional division we are concerned with in step 5 is the faulty circuit. As shown in the following diagram of a transistor amplifier, the circuit consists of many parts. We must wait until step 6--failure analysis -- to isolate the faulty parts.



Transistor Amplifier Circuit

THE CORRECT APPROACH

Before you continue the troubleshooting procedures into step 5, you should pause and assimilate all of the data obtained at this point which may aid you in performing the next step. After completing step 4, you know that all of the inputs to the faulty function are correct and that one or more of the outputs is incorrect or nonexistent. The incorrect output waveform(s) obtained in step 4 should be analyzed to obtain any information which may indicate possible trouble areas within the functional unit. It is important to remember that the original symptoms and clues obtained in the first two steps should not be discarded merely because steps 3 and 4 are completed. This information will be helpful throughout the troubleshooting procedure, and should be reviewed, together with all clues discovered in subsequent steps, before continuing to the next step.

After completing step 4, the technician should:

SELECTIONS:

A. Immediately begin step 5.

B. Repeat step 4.

C. Review all previous steps.

A. Immediately begin step 5.

No. Before beginning step 5 it is important to analyze all information. The importance of each step can not be over emphasized. Step 4 may have localized the faulty function, but only because of the information obtained in the previous steps. Each step provides useful information that will aid in the continued process of narrowing down the trouble area. The characteristics of the incorrect output(s) of a functional unit may be important clues to the possible trouble locations, and often enable the technician to arrive at a logical decision which eliminate unnecessary tests.

B. Repeat step 4.

No. The principle of logic troubleshooting is to make proper use of the information known in order to eliminate time wasted in making unnecessary tests. If the previous step had been correctly performed repeating the step would provide little if any additional information. A review of all material should be made at this time.

C. Review all previous steps

You are correct. The basic principles of logical troubleshooting should be followed until the trouble has been located. This requires that the technician make proper use of all information obtained before making decisions concerning the next step. A review of this information lets him know exactly where he stands before he begins the next step.

Step 5 should be a continuation of the narrowing-down process, and the "input-conversion-output" principle should by employed in each part of this step. Each functional unit has a separate function within an equipment, and within each functional unit there may be two or more groups of circuits, each with sub-function. This means that the input to each circuit group (sub-function) is converted, and the output emerges in a different form. An understanding of the conversions which occur within a functional unit makes it possible to logically select possible trouble areas within the unit. Testing is then performed to isolate the defective circuit group. The same principles are applied to the circuit group to locate the faulty circuit within the group.

SERVICING BLOCK DIAGRAMS

The purpose of the servicing block diagram is to provide you with a pictorial guide for use in step 5. Figure 14, fold-out page 4 is such a

diagram for the receiver unit of a transceiver set. There will also be a servicing block diagram for every other unit in the transceiver set--modulator, transmitter, and power supply. Occasionally, the entire equipment will be represented by one service block diagram, as shown in figure 18 fold-out page 5. Figure 19, fold-out page 6, represents a servicing block diagram for a radar receiver.

The use of a servicing block diagram is facilitated by the fact that all circuits within the functional unit are enclosed in heavy dashed lines, while circuits comprising a circuit group within the function are enclosed with light dashed lines. Within each dashed enclosure is the name of the functional unit or circuit group it represents. Main signal or data flow paths are represented by heavy lines, and secondary signal or data paths are represented by lighter lines.

Notice in figure 18 that waveforms are given at several test points. Star test point symbols represent points which are useful for isolating faulty functional units, and circled test point symbols represent points which are helpful in locating faulty circuits or circuit groups.

Although there are variations in servicing block diagrams, the diagram illustrated in figure 18 is typical of many servicing block diagrams. Which of the following statements best summarize the over-all purpose of the servicing block diagram?

SELECTIONS:

A. It provides a diagram showing components, waveforms and test points at the output of each circuit.

B. It identifies all major test points.

C. It provides a pictorial guide for the technician in performing step 5 of the troubleshooting procedure.

A. It provides a diagram showing components, waveforms and test points at the output of each circuit.

No. A servicing block diagram does not show components. These are shown on a schematic diagram to be discussed later. Waveforms are shown only at major test points throughout the diagram - not at the output of each circuit. Proper use of the servicing block diagram will encourage logical reasoning. Each step of the procedure is based on logical reasoning.

B. Its main purpose is to identify all major test points.

No. The servicing block diagram does identify all major test points, but this is no more important than the major and minor signal paths shown or the circuit groups outlined. This statement describes only one of the features of the servicing block diagram.

C. It provides a pictorial guide for the technician in performing step 5 of the troubleshooting procedure.

Yes. It's for your use as a guide from which you can work during a troubleshooting problem. The servicing block diagram is one of the aids to troubleshooting which enables you to continue through the procedure in a logical and methodical manner.

BRACKETING

Another aid to troubleshooting is the "bracketing" process, which provides the technician with a physical means of narrowing down the trouble area to a faulty circuit group and then to a faulty circuit.

Once the tests in step 4 - localizing the faulty function - have been performed and the faulty unit isolated, the bracketing process begins by placing brackets (either mentally or with a pencil) at the good input(s) and at the bad output(s) of the faulty function in the servicing block diagram. You know at this point that the trouble exists somewhere between the brackets. The idea is to make a test between the brackets and then move the brackets one at a time (either input or output bracket) and then make another test to determine whether the trouble is within the new bracketed area. This process continues until the brackets isolate the defective circuit.

The most important factor in bracketing is determining where the brackets should be moved in this narrowing-down process. This is determined on the basis of the technicians deductions from the analysis of systems and previous tests, the type of circuit paths through which the signal flows, and the accessibility of test points. All moves of the brackets should be aimed at isolating the trouble with a minimum number of tests.

Which of the following statements best describes the term "bracketing" as applied to electronic equipment troubleshooting?

SELECTIONS:

A. Bracketing is the process whereby a trouble is isolated between a satisfactory input signal and a faulty output signal.

B. Bracketing is the process of injecting a test signal for evaluating a suspected circuit.

C. The bracketing process provides a means for testing the input and output of a circuit or a circuit group.

A. Bracketing is a process whereby a trouble is isolated between a satisfactory input signal and a faulty output signal.

Yes. This form of isolation is the basis of the bracketing technique, which is an important troubleshooting aid used in step 5 in our six-step troubleshooting procedure--localizing trouble to the circuit.

B. Bracketing is the process of injecting a test signal for evaluating a suspected circuit.

No. Evaluating a circuit's operation by injecting a test signal may be used in the bracketing process after the trouble has been isolated to a circuit group. However, this represents only one step of the bracketing process, and does not describe the term.

C. The bracketing process provides a means for testing the input and output of a circuit or a circuit group.

Brackets may be placed around a suspected circuit or circuit group, but they do not give you the means for testing it. This must be performed with signal generators, oscilloscopes, meters, etc. Bracketing is used to keep the required testing to a minimum by employing logical reasoning.

CIRCUIT GROUPS

You must be able to recognize circuit groups and to sub-divide a block diagram of a functional unit into circuit groups before you can apply the bracketing procedure. A circuit group is one or more circuits which form a signal functional division of a functional unit of an equipment. A typical radio receiver contains the following circuit groups: r-f amplifier, converter, i-f amplifiers, detector, and audio amplifiers. A typical radio transmitter contains the following circuit groups: master oscillator, intermediate power amplifiers, and final power amplifier.

You can see that the circuit groups named above perform sub-functions in a receiver or transmitter, and that their combined operations perform the complete function of the unit they constitute.

Refer to the servicing block diagram shown in figure 18, fold-out page 5, and determine which of the selections below contains circuit groups only.

SELECTIONS:

A. Modulator, receiver-transmitter.

B. I-F circuits, video circuits, and a-f-c circuits.

C. I-F circuits, trigger circuits, and pulse amplifiers.

A. Modulator, receiver, and transmitter.

None of these are circuit groups. The modulator is a functional unit which is divided into circuit groups, and the receiver-transmitter unit is a functional unit which is also divided into circuit groups.

B. I-F circuits, video circuits, and a-f-c circuits.

Yes. This is a list of circuit groups. Other circuit groups in figure 18 include: STC circuits, trigger circuits, pulse circuits, and high-voltage circuits. Each of these circuit groups performs a sub-function within its functional unit.

C. I-F circuits, trigger circuits, and pulse amplifier.

Wrong. The pulse amplifier is an individual circuit which is part of a circuit group, and does not form a sub-function by itself. The I-F circuits and trigger circuits both qualify as circuit groups because they consist of a group of circuits that perform a single function.

TYPES OF SIGNAL PATHS

The signals associated with a circuit group normally flow in one or more of four different types of signal paths. These include the linear path, convergent-divergent path, feedback path, and switching path.

The linear path is a series of circuits arranged so that the output of one circuit feeds the input of the following circuit. Thus, the signal proceeds straight through the circuit group without any return or branch paths. This is shown in part A of figure 20.

The convergent-divergent path may be any of three kinds: divergent, convergent, and the combined convergent-divergent. A divergent path is one in which two or more signals paths leave a circuit, as shown in part B of figure 20. When two or more signal paths enter a circuit, the path is known as a convergent path. An example is shown in part C of Figure 20. A convergent-divergent path is one in which a circuit group or single circuit has multi-inputs and multi-outputs, as shown in part D of figure 20. This type is not as common as the convergent path and the divergent path.

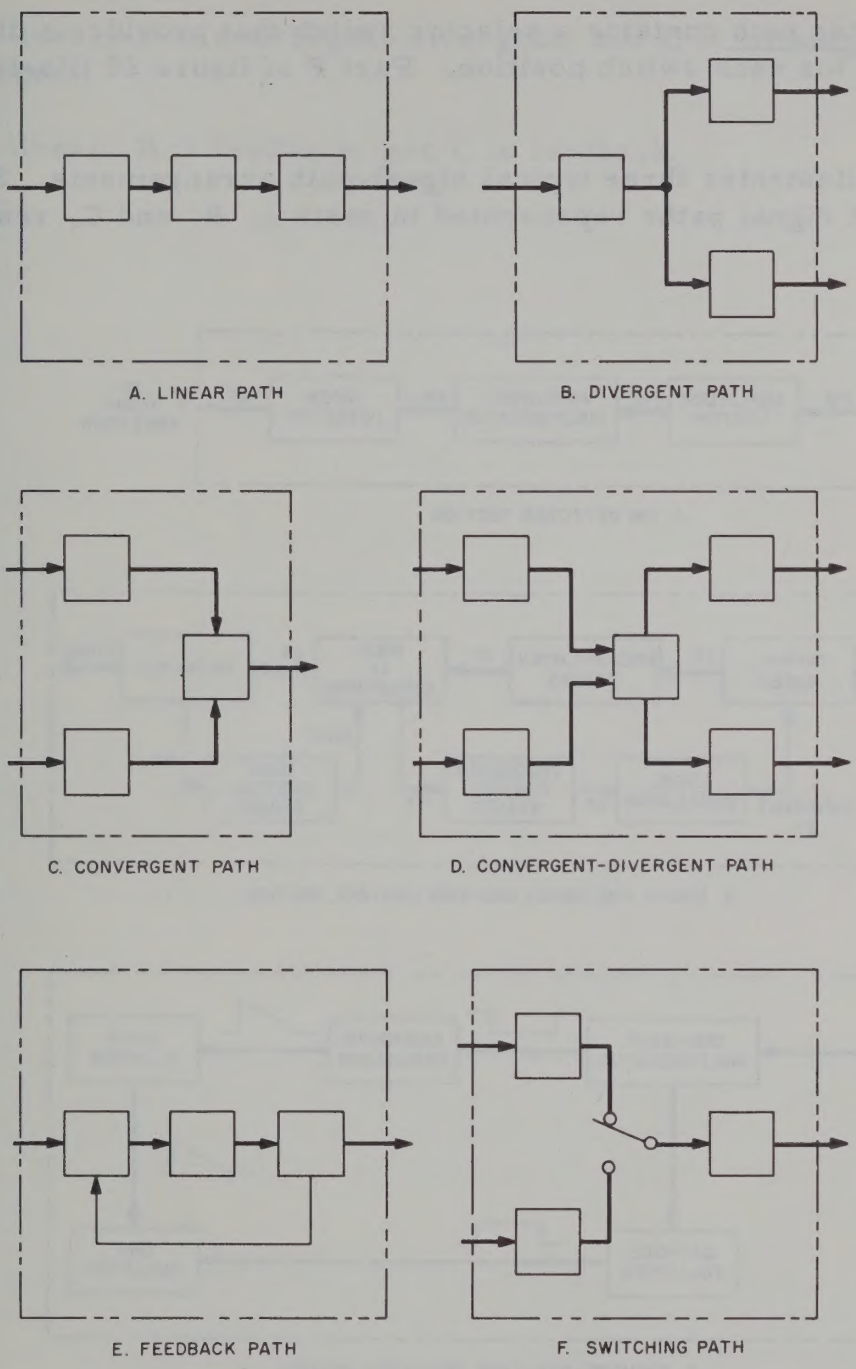
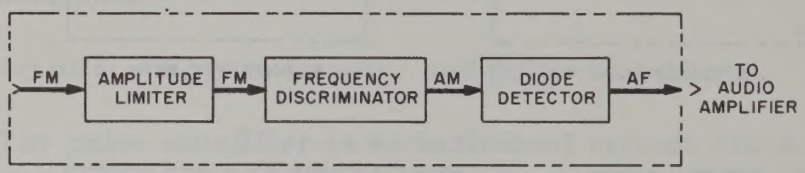


Figure 20. Types of Signal Paths

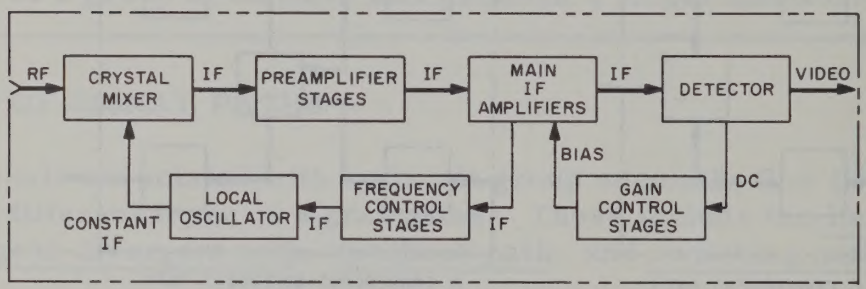
The feedback path is a signal path from one circuit to a point or circuit preceding it in the signal-flow sequence. This is shown in part E of figure 20.

The switching path contains a selector switch that provides a different signal path for each switch position. Part F of figure 20 illustrates this type.

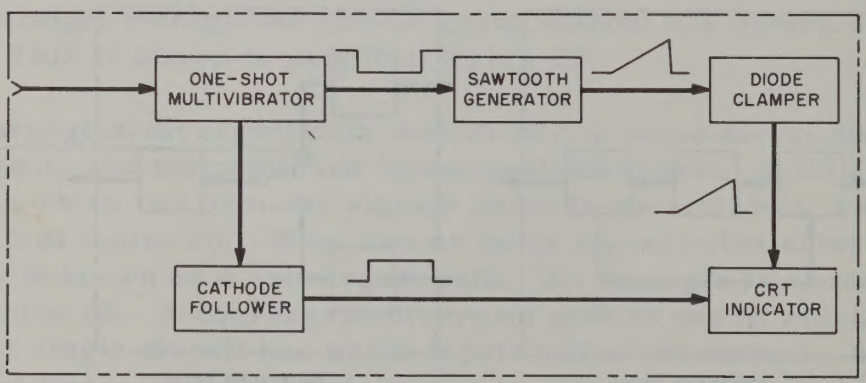
Figure 21 illustrates three typical signal-path arrangements. Select the types of signal paths represented in parts A, B, and C, respectively.



A. FM DETECTOR SECTION



B. RADAR FREQUENCY AND GAIN CONTROL SECTION



C. CATHODE-RAY-TUBE INDICATOR SYSTEM

Figure 21. Typical Signal Path Arrangements

SELECTIONS:

A. A is linear, B is feedback, and C is convergent-divergent.

B. A is linear, B is convergent-divergent, and C is convergent-divergent.

C. A is linear, B is feedback, and C is feedback.

A. A is linear, B is feedback, and C is convergent-divergent

Yes. The signal proceeds directly through circuit group A without any return or branch paths. In circuit group B, the second detector and the main i-f amplifier blocks have outputs which are returned to the main i-f amplifier and mixer, respectively, constituting a feedback path. The signal in group C diverges at the multivibrator and converges at the indicator.

B. A is linear, B is convergent-divergent, and C is convergent-divergent.

No. Although different signal paths enter and leave the main i-f amplifier block (part B) and diverge from the detector, these secondary branches return to points preceding their source in the signal path. Therefore, part B represents a feedback path. Note that this differs from part C which is a convergent-divergent circuit because the signals diverge from the one-shot multivibrator and diverges at the CRT indicator. A divergent-convergent path might be considered as a circuit having multiple inputs and outputs.

C. A is linear, B is feedback, and C is feedback.

No. Part A is a linear path and part B is a feedback path, but part C shows no return path; therefore, it cannot be a feedback path. The two signals proceed in the same direction; they diverge at the multivibrator and converge at the indicator.

BRACKETING PROCEDURES

You have been introduced to several aids to be used in step 5; the servicing block diagram, bracketing procedures, dividing units into circuit groups, and recognizing the four basic types of signal paths. Now it is time to show how these aids are employed in this trouble-shooting step.

Before the beginning the bracketing procedure, the data obtained in the previous steps should be reviewed and evaluated, and the servicing block diagram should be employed to provide a pictorial guide of the signal paths throughs through the faulty functional unit. The functional unit is divided into circuit groups, and the sub-function of each circuit group is considered to determine which could cause the observed symptoms. The bracketing procedure begins by placing opening brackets at the good inputs, and closing brackets at the bad outputs, of the functional unit on the servicing block diagram.

When tests have indicated a list of possible defective circuit groups, a bracket is moved to the input or output of one of these circuit groups, and further tests are made to verify whether the test points within the circuit group are good or bad. The brackets are thus moved, one at a time, until they enclose a single circuit group. A circuit group is bracketed when an opening bracket indicates a satisfactory signal at the input of the circuit group and closing bracket indicates an unsatisfactory signal at the output.

At this point--when the defective circuit group has been located--the servicing block diagram is used to determine the type of signal path within the circuit group. The bracketing procedure thus continues until the bracketing encloses a single circuit.

Initially, which of the following should you place brackets around?

SELECTIONS:

A. Possible faulty circuits.

B. Possible faulty circuit groups.

C. Faulty function.

A. Possible faulty circuits.

No. This could be very time consuming if brackets were placed around each circuit. The faulty circuit is not considered until the trouble has been isolated to a circuit group. Placing brackets around suspected circuits at the beginning of step 5 would be deviating from the logical approach, which is designed to eliminate as many circuits as possible with each test. The faulty function must be located prior to isolating either faulty circuit groups or faulty circuits.

B. Possible faulty circuit groups.

No. The faulty circuit group must be located first by using the bracketing method to locate the faulty function. Brackets are then placed around the suspected faulty circuit groups and the inputs and outputs verified before placing the brackets around another circuit group.

C. Faulty function.

Correct. You first place brackets at the input(s) and output(s) of the functional unit which has been isolated in steps 3 and 4. You know that the first bracket indicates that the input signal is good at this point, and that the second bracket indicates the point of an improper output signal. Only one bracket should be moved at a time, and a test should be made at each new point to determine whether the bracket should remain there. The choice of the point to which a bracket is moved is determined by the signal paths within the unit and your general knowledge of the circuit operation.

Throughout this process, the tests are made by signal tracing and/or signal substitution. Signal tracing is accomplished by examining the signal at a test point with an oscilloscope, voltmeter, power meter, etc. An example of this application is in a transmitter which provides its own signal (master oscillator). The output of any stage from the oscillator to the antenna can be checked simply by connecting the proper test equipment at that point.

Signal substitution is a method of injecting an artificial signal into a circuit to check its performance. A radio receiver is an example of an equipment which can be tested by this method. If a signal generator is used to provide the proper signal at some test point in the receiver, a good output at the speaker indicates that the area between the test point and the speaker is free of trouble.

An example of the bracketing procedure can be shown by referring to figure 22, which represents a faulty functional unit. Step 4 - Localizing the Faulty Function - indicated a good input at test point "A" and a faulty output at test point "E" indicating a trouble located between these two points.

Signal tracing would normally be used since the signal at point "A" is known to be good. The signal at test point "C" would be the first logical place to check since this check would eleminate half of the circuit. (This will be discussed later in the text.) The signal at test point "C" can be checked by placing a meter or scope at this point. If the signal is satisfactory, the input bracket would be moved from point "A" to point "C". The next check at point "D" would then isolate the defective circuit. If the test was satisfactory, the trouble would be in circuit group IV; if unsatisfactory the trouble would be in circuit group III. Only the input bracket was moved. If the test at point "C" had been unsatisfactory, the output bracket would have been moved to this point. The next check at test point "B" would then isolate the defective circuit. If the signal is satisfactory, the trouble would be in circuit group II; it unsatisfactory the trouble would be in circuit group I. In this case, only the output bracket was moved.

If signal injection is used, a test signal would be injected at test point "C", and the output checked at test point "E". If the results are satisfactory, the output bracket is moved to point "C", and a signal is injected at test point "B" to isolate the defective circuit. If the signal is nor correct at point "E", the trouble should be isolated between points "C" and "E" and the input bracket moved to point "C". Injecting a signal at point "D" would then isolate the defective stage.

Signal substitution and/or signal tracing should be employed during step 5:

SELECTIONS:

A. To test every circuit in the faulty circuit group.

B. To test every circuit group in the faulty function.

C. To test probable faulty circuit groups each time the brackets are moved.

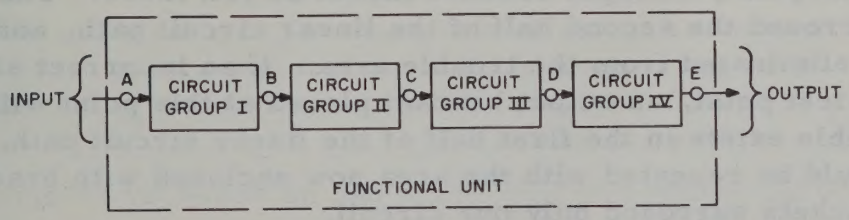


Figure 22. Functional Unit with Input and Output Brackets

A. To test every circuit in the faulty circuit group.

No. Once the trouble has been isolated to a circuit group, each test should eliminate as many circuits as possible. Logical troubleshooting should reduce the number of tests required to locate the faulty circuit to a minimum.

B. To test every circuit group in the faulty function.

No. Tests are made only on those circuit groups which could cause the symptoms associated with the trouble. When a faulty circuit group is located, the troubleshooting procedure should concentrate on that circuit group, even if all possible faulty circuit groups have not yet been tested.

C. Every time a bracket is moved.

Yes. By using the bracketing technique, the technician has a record of the last good input test point and bad output test point checked, and thus can keep track of his progress in narrowing down the trouble area. Every time he makes a logical decision to move one of the brackets to a new location, he must test that point with the signal substitution and/or signal tracing method, to determine whether the bracket should be labeled as a good or bad test point. Opening brackets should be left only where a signal is good, and closing brackets should be placed only where the signal is incorrect.

The first method of bracketing to be considered will be the method used for linear circuit arrangements. The best method of troubleshooting this type of circuit path is the half-split method. Suppose that you have brackets at the input and output of a number of circuits or circuit groups in which the signal path through all circuits is linear. Unless the symptoms point to one circuit in particular which might be the trouble source, the most logical place to move a bracket is to a convenient test point near the center of the bracketed area. If a test indicates that the signal is good at this point, an input bracket should be left there. The brackets will then surround the second half of the linear circuit path, and the other half will be eliminated from the trouble area. If an incorrect signal is found at the test point, an output bracket placed at this point will show that the trouble exists in the first half of the linear circuit path. This process should be repeated with the area now enclosed with brackets until the brackets surround only one circuit.

Consider the functional unit shown in figure 23, fold-out page 7. Notice that the brackets indicate that this is a faulty function. The first place to move a bracket should be to the output of circuit:

SELECTIONS:

A. A4.

B. B2.

C. B3.

A. A4.

No. This is not following the half-split method. If the trouble were in circuit group A, the trouble area would be reduced considerably by this step; however, there are twice as many circuits in the other part of the functional unit. If circuit group is operating properly, then there are three groups left which may contain the trouble.

B. B2.

No. You have followed the half-split method too closely, and have forgotten one of the fundamental principles of step 5. The trouble should be isolated to a circuit group before checking circuits within a circuit group, even if the exact center of the function is not at a circuit group output. Besides, test points are usually more convenient at circuit group outputs than within a circuit group.

C. B3.

Very good! You have followed the principles of step 5 and have correctly used the half-split method. The trouble should be isolated to a circuit group before checking a circuit within a circuit group, even if the exact center is not at a circuit group output. There should be a convenient test point at the output of circuit B3, since it is also the output of circuit group B. Assume in this case that a signal generator is connected to the input of the functional unit, to provide the correct input, and than an oscilloscope at the output indicates an incorrect signal. The brackets should now surround circuit groups A and B. (Had the signal been correct, the brackets would have been placed around circuit groups C and D.)

The next step in the procedure is to move a bracket to the output of circuit group A or to the input of circuit group B. It is usually more convenient to move an oscilloscope or meter probe than a signal generator input (especially if the frequency is different at the other test point); therefore, in this example, you could move the scope leads to the output of A4.

Now, if the signal is incorrect at this point, you can move the output bracket there and group A will be enclosed. The next step is to check the output of circuit A2; if this output is correct, the input bracket should be moved to this point. Now only two circuits (A3 and A4) are inside the brackets. The next obvious step--to check the output of A3--will isolate the trouble to a circuit.

With the half-split method, a defective circuit can be located with a minimum of three and a maximum of four tests. By using a hit-or-miss method of testing the circuits in sequence, the trouble may be located with one test or a maximum of eleven tests.

It is unusual to find a complete functional unit with only one linear signal path; however, the half-split method can be applied to any part of a unit which contains a linear path.

Convergent-divergent signal paths require a different technique. This type of signal path is not as easily recognized as linear paths; however, if you follow the definitions previously given, you should have little difficulty with this part of the procedure.

Consult figure 14, fold-out page 4. Which circuit groups contain convergent, divergent, and convergent-divergent paths?

SELECTIONS:

A. Convergent, converter; divergent, none; convergent-divergent, audio amplifier.

B. Convergent, i-f amplifier; divergent, detector; convergent-divergent, audio amplifier.

C. Convergent, converter; divergent, audio amplifier; convergent-divergent, none.

A. Convergent, converter; divergent, none; convergent-divergent, audio amplifier

Yes. The outputs of the r-f amplifier and the r-f oscillator converge at the mixer in the converter circuit group. The output of V7 diverge, and the two signal paths later converge at T10 in the audio amplifier. There are no circuit groups with only divergent paths; the second output of the detector is a feedback path to the i-f amplifiers.

B. Convergent i-f amplifier; divergent, detector; convergent-divergent, audio amplifier.

No. The second output of the detector, which is returned to the i-f amplifier circuit group, forms a feedback path as it is applied to a previous circuit. Therefore, neither of these two circuit groups contain a convergent or a divergent path.

C. Convergent, converter; divergent, aduio amplifier; convergent-divergent, none.

Wrong. The audio amplifier contains convergent-divergent paths. The signals diverge from V7 and converge at T10. Remember that the convergent-divergent paths apply to circuits or circuit groups that have multiple inputs and multiple outputs.

The audio amplifier circuit group of the receiver unit used previously is repeated in figure 24. fold-out page 8. Assuming that a trouble has been isolated to this circuit group, brackets should be placed at the input of V7 and the output of T10. An audio signal can be injected at the input of the audio amplifier circuit group, and an oscilloscope can be used to trace the signal within the circuit group.

Since this is a convergent-divergent signal path, the first test should attempt to isolate the trouble to one of the two signal paths. A test at point 1 will establish whether or not the signal is correct at the end of singal path 1. If the signal is satisfactory, this path is eliminated as a trouble area; if the signal is unsatisfactory, the output bracket should be moved to this point. If the latter case is true, the next test point should be where signal path 1 diverts from the input signal path (2A). A bad signal at this point will place the brackets around V7, a good signal at 2A would direct you to test at 3A, which will isolate the trouble to either V8 or V10. If the test at 1 is satisfactory, the output of signal path 2 should be checked (2B). A correct signal at this point will indicate a defective T10; an incorrect signal at test point 2B

will direct you to a test at 3B, which will isolate the trouble to either V7 or V9. Follow the sequence of this procedure, as shown in figure 25 on the same fold-out page.

The first steps in the bracketing procedure for convergent-divergent circuits should be:

SELECTIONS:

A. Check all divergent and convergent points.

B. Isolate the trouble to one signal path.

C. Apply the half-split method to each signal path.

A. Check all divergent and convergent points.

No. Although the test should begin at either a convergent or a divergent point, the results of each test should determine where to make the next test. Testing each convergent-divergent path would be a waste of time and would not follow the logical approach previously outlined.

B. Isolate the trouble to one signal path.

Yes. The convergent and divergent paths should be checked until the trouble is isolated to one of the signal paths, and then the half-split method can be applied to the faulty linear signal path.

C. Apply the half-split method to each signal path.

No. The half-split method is used on a linear path. You must first determine which path of the convergent-divergent path is faulty. Once this has been determined the half-split method could be applied to the linear portion to isolate the trouble area.

The next method of bracketing to be considered is applied to feedback signal paths. Before describing this method, a short discussion of the principles of feedback circuits will be necessary.

As stated previously, a feedback signal path is one in which a signal is removed from some point in a circuit chain and applied to a point preceding its source. Since this feedback signal is combined with the original signal, it will tend to either increase or decrease the signal amplitude. If the feedback signal arrives back at the main signal path in phase with that signal, it is called regenerative feedback and will increase the gain of the circuit chain. When the feedback signal is out of phase with the main signal, it is called degenerative feedback and will decrease the circuit gain.

Regenerative feedback is used extensively in oscillator circuits. This type of feedback makes it possible for an oscillator to generate an a-c signal. Sometimes regenerative feedback is used to increase the gain of amplifier; however, its tendency to cause oscillations limits its use in amplifiers. Degenerative feedback is often employed in amplifiers to decrease distortion and increase the bandwidth of a circuit. Another application of degenerative feedback is in automatic-volume-control (a-v-c) systems. In this case the feedback has the function of keeping the output of a receiver essentially constant despite varying input signal strength.

Which of the following selections describes the common result of both types of feedback?

SELECTIONS:

A. Both types subtract from the amplitude of the main signal input.

B. Both types alter the effective operating characteristics of the circuitry in the main signal path.

C. Both types increase the effective gain of the circuits in the main signal path.

A. Both types subtract from the amplitude of the main signal input.

No. You have missed the point. Regenerative feedback is coupled back to the input in such a manner that the signal will be reinforced, resulting in an increase in gain, while degenerative feedback results in a cancellation of part of the signal and results in a decrease of gain.

B. Both types alter the effective operating characteristics of the circuitry in the main signal path.

Yes. Degenerative feedback alters the characteristics by subtracting from the main signal, thereby reducing the overall gain. Regenerative feedback alters the characteristics by adding to the main signal, thereby increasing the overall gain.

C. Both types increase the effective gain of the circuits in the main signal path.

No. Degenerative feedback is out of phase with the main signal input, and thus reduces the over-all gain of the main signal path. Regenerative feedback is in phase with the main signal input, and thus increases the over-all gain of the main signal path.

An example of degenerative feedback is shown in figure 26, fold-out page 9. The i-f amplifiers amplify the intermediate-frequency signals, and the detector demodulates these signals, producing an audio output. The detector also detects the a-v-c signal, which is a d-c voltage proportional to the amplitude of the input signal to the detector. This a-v-c voltage is applied as a negative bias to V3 and V4, and results in a decreased gain in these two stages. When a strong signal is received from the mixer, the a-v-c voltage output of the detector prevents the audio (main signal) from becoming too large. A weak input signal, however, does not result in a large a-v-c voltage; thus sufficient gain in the circuit is maintained to amplify the small signal.

When the troubleshooting circuits with feedback paths, it is important to consider the type of feedback and the function of feedback in the circuit. Since a regenerative feedback path results in an increased circuit gain, a trouble in the feedback path results in a decreased output signal. Conversely, a trouble in a degenerative feedback path results in an increased output signal.

If a trouble is isolated to the circuit in figure 26, you should analyze the output to determine whether the fault is most likely to be in the main or the feedback signal path. If the output is weak or nonexistent when the input is normal, the hlaf-split method can be applied to the main signal path. An output signal which is considerably larger than normal for a given input is an indication that the fault is in the feedback path. In this case the a-v-c output of the detector should be checked first (test point 1A). A low a-v-c voltage indicates a trouble in the detector. A normal or greater than normal a-v-c voltage indicates a fault in the a-v-c input to either V3 or V4. The next check should be the output of V3. A higher than normal signal here indicates a defective a-v-c input circuit of V3; a normal output from V3 points to a similar trouble in V4. Figure 27 (on the same page) shows the sequence of tests for this example.

If the output of a group of circuits containing a degenerative feedback loop is low, the trouble is probably in the:

SELECTIONS:

A. Main signal path.

B. Feedback path.

C. Input to the circuit group.

A. Main signal path.

Correct. When the output of a circuit containing a negative feedback loop is low, trouble is indicated in the main signal path rather than in the feedback path.

B. Feedback path.

Wrong. If part of the signal is fed back out of phase to a previous stage, part of the signal would be cancelled, resulting in a decreased output; therefore, degenerative feedback results in a decrease of the input signal. A trouble in the feedback path will normally cause an increase in the output.

C. Input to the circuit group.

This is not the best choice. A low input could result in a low output but previous tests should have shown the input to be satisfactory, otherwise this circuit group would never have been bracketed. A more logical step would be to check the main signal path.

Another method of troubleshooting circuits containing feedback loops is to disable the feedback loop. This may be accomplished by disconnecting the feedback path (opening the loop) or by shorting the feedback signal to ground. The first method is sometimes inconvenient, and the second method should be used only when it has been determined that shorting the signal to ground will not cause damage to the circuit.

Disabling the a-v-c loop is convenient in the case of a receiver with an AVC ON-OFF switch. If a trouble is located in the circuit containing the a-v-c loop, the switch can be used to determine whether the trouble still exists without a-v-c,

The last type of signal path is the switching path. You have seen how electronic equipments are composed of various circuit chains interconnected to perform a desired task. Control of these circuits is usually accomplished by the use of switches placed directly in the circuits, or by remote switching relays.

In order to isolate faulty circuits along a switching branch, we initially test the final signal output for the branch following the switch. When the switch is a multiple-contact type, each contact may be connected to a different circuit branch. In this case, it may be necessary to place the switch in each position and check the final output of the branch associated with that position. If the symptoms and data point to one specific branch, it may not be necessary to check every switch position.

Once this test has been performed and the trouble is isolated to one or more branches, the suspected branches should be checked to locate the faulty branch. The next step is to apply the half-split, convergent-

divergent, or feedback method, as required, to isolate the faulty circuit.

An example of a switching arrangement is shown in figure 28, fold-out page 10. This figure shows the i-f amplifier and detector circuits for a radar receiver. The operation of a pulse radar system involves the transmission of pulses of r-f and "listening" with the receiver for echo pulses reflected from a target. For short-range operation a very narrow pulse is normally used (.25 to 1 usec); for long-range operation a wider, more powerful pulse is required (2 to 5 usec).

The narrow pulses contain more high frequencies than the wider pulses; thus for short-range operation the receiver must have a wider bandwidth to prevent distortion of the narrow target echoes. During long-range operation, however, receiver sensitivity is more important than target resolution; therefore, some radar receivers have a separate narrow-band i-f amplifier for this purpose. Switch S1 (A and B) operates automatically when the set is changed from short-range to long-range operation.

Assume that a trouble has been isolated to the circuits shown in figure 28. The information obtained in the symptom elaboration step should be analyzed to determine the first point to which a bracket should be moved in this circuit chain. By observing the output of the detector (with a proper i-f signal injected at the input of V1), the switch can be used to help isolate the trouble. If the output of V8 is incorrect only during narrow-band operation (short range), the trouble is in the wide-band circuit group; if the output trouble is present for both positions of the switch, the trouble is in V1 or V8, or in the switch itself. The rest of the bracketing procedure consists of narrowing down the trouble to a single circuit within the faulty branch. Figure 29, on the same page, shows the test sequence for this faulty switch. Should a trouble be isolated to a circuit which is connected to one of the switch contacts, a check should be made between the circuit and the switch before that circuit is bracketed.

Which one of the following selections describes the first step in bracketing a trouble in a switching circuit.

SELECTIONS:

A. Test the signal directly before and immediately after each switch in the signal path.

B. Observe the output of the final stage after the switch as the switch positions are changed.

C. Inject a signal at the input to the switch, and test each output point.

A. Test the signal directly before and immediately after each switch in the signal path.

No. This method would locate a trouble in one branch before the switch, or a faulty switch, but what about the other branches which may be connected to the same switch? One of these branches may be faulty. In this case the output of each branch would have to be checked and valuable time would be wasted. A check at the output of the final stage as the switch is rotated would be the most logical step.

B. Observe the output of the final stage after the switch as the switch positions are changed.

Yes. This information can often be obtained from the symptom elaboration step, and may not require an actual test at this time. Since a switch connects different combinations of circuit branches, it can be used to help isolate the trouble to one or more of the branches.

C. Inject a signal at the input of the switch, and test each output point.

No. Such a procedure would test only the switch, and in most cases would provide no useful information. Efficient test procedures are always designed to eliminate as many circuits as possible with each test point selected.

BRACKETING APPLICATIONS

To show how the bracketing procedures are applied in step 5, localizing trouble to the circuit, an example will be used in which you will start with a faulty unit and follow the principles of troubleshooting until you have isolated a faulty circuit.

Refer to figure 14, fold-out page 4. This is the receiver section of the transceiver which you studied previously. Assume a condition in which only a "hissing" or buzzing sound is heard at the loudspeaker as the receiver is tuned throughout its range, and this sound is not present when the volume control is turned to minimum. These symptoms indicate that the trouble is in a circuit preceding the volume control. However, to verify this, a positive check should be made. Until the check is performed, the brackets should be placed at the antenna and speaker. The check can be made by either of two methods. One method is to inject an r-f signal at the antenna and test the signal at the detector output with an oscilloscope or signal tracer. Another method, which is convenient for radio receivers, is to inject an audio signal at the input of the audio amplifiers and listen to the speaker. Assume that the test

shows the trouble to be in a circuit ahead of the audio amplifier circuit group. The output bracket should now be moved to the output of the detector.

Where should the next test be made?

SELECTIONS:

A. Pin 1 of V3.

B. Pin 3 of V6.

C. Pin 1 of V4.

A. Pin 1 of V3.

Yes. This is a convenient test point and would isolate the trouble to two circuit groups; the i-f amplifiers and the detector group, or the mixer and r-f amplifier group. The first step is to isolate the faulty circuit group using the least number of tests.

B. Pin 3 of V6.

No. You are not following the principles of logical troubleshooting. This test would eliminate only one stage, the detector, and the symptoms do not indicate that this circuit is more likely to be faulty than the other circuits within the bracketed area.

C. Pin 1 of V4.

No. You have selected a test point within a circuit group. Your first step should have been to isolate the faulty to one of the circuit groups remaining inside the brackets before making checks within a specific circuit group.

There are two methods of making a test at this point--signal injection and signal tracing. If a signal tracer is available, a signal generator can be adjusted to provide a modulated r-f signal at the antenna, and the signal tracer can then check any test point from there to the speaker. The receiver may be tuned to a station; however, this is not always reliable. The test can also be made by injecting a modulated i-f signal at the grid of V3 and again listening to the speaker. Assume in this case that the output is satisfactory. The output bracket should now be placed between V2 and V3.

The next test point will obviously be one of two possible choices. Which of these should be checked first.

SELECTIONS:

A. Pin 2 of V2.

B. Pin 8 of V11.

A. Pin 2 of V2.

Correct. This test will isolate the trouble to either the r-f amplifier or the converter. If the previous tests were made by signal tracing, the signal tracer can be moved to this point; otherwise, the signal generator can be used to apply a modulated r-f signal at this point. Assume that in this case only the noise previously mentioned is heard at the speaker. The brackets now enclose only the converter group.

B. Pin 8 of V11.

No. Although either of the selections would eliminate only one circuit, there are two reasons that this one should not be selected first. You are dividing a circuit group before isolating the trouble to one whole circuit group, and the r-f oscillator is not in the main signal path.

The next test--V11 output--can be made by substituting the correct oscillator frequency with a signal generator or by checking the output with an oscilloscope or voltmeter. If this test indicates a satisfactory output from the oscillator, another input bracket can be placed at pin 4 of V2; the brackets will now surround the mixer circuit.

Another example of applying the bracketing procedure to step 5 will use figure 19, fold-out page 6. This is the receiver unit of a ground radar set, and it includes several special circuits as well as the basic radar receiver circuits. The sensitivity time control circuits provide a pulse which reduces the receiver gain when the transmitter fires a pulse of rf, and gradually increases the receiver sensitivity after the transmitter pulse is completed. This reduces the clutter on the scope, which otherwise would result from strong echoes from nearby targets.

The anti-jam circuits are used to reduce the effect of strong echoes or jamming signals which tend to block the i-f amplifiers. This type of circuit is sometimes called instantaneous automatic gain control. The circuit detects large target or jamming pulses and immediately feeds back a bias which reduces the gain of the i-f amplifier and prevents overdriving the receiver.

The moving-target-indicator (MTI) circuits allow only moving targets to be applied to the radar scope, and prevent stationary ground targets from cluttering up the picture. This is accomplished by delaying all video signals in one channel while a parallel channel amplifies undelayed pulses. The video comparator compares the two signals; if a target has not moved during the time between transmitter pulses, both signals will arrive at exactly the same time and will thus be cancelled.

The bi-level video amplifier is a two-channel amplifier which amplifies video pulses representing moving targets and applies them to separate indicators.

In this example we assume that a trouble has been isolated to the receiver unit. The symptoms are: no raw video or MTI video, regardless of the position of the STC switch, the anti-jam switch, the FTC relay, or the MTI switch. All inputs are good and the delayed sync pulse output is good.

Considering this information, which circuit group is most likely to contain the trouble?

SELECTIONS:

A. I-F amplifier.

B. Video group.

C. MTI group.

A. I-F amplifier.

Very good. The fact that there is no raw video output eliminates the MTI group as a possible trouble, since this circuit group is not in operation when the MTI switch, S2, is in the OFF position. This is a good example of the switching method of troubleshooting. The trouble is now narrowed to two possible circuit groups--the i-f amplifier and the video group. The switch also eliminates the video amplifiers and cathode follower as possible trouble areas because a trouble in these circuits would not affect the MTI video.

B. Video group.

No. Although this is a possible faulty circuit group, here is another choice which is far more likely to be at fault. This group is eliminated when the MTI switch is placed in the ON position. In this position, MTI video would have been satisfactory had the trouble been in the video group.

C. MTI group.

Absolutely not! There are two good reasons for not selecting this circuit group. First, the correct delayed sync pulses indicate that one half of this circuit group is operating. The second and more important clue is the fact that raw video is not present. This could not result from a defective MTI circuit.

The next step in our logical troubleshooting procedure would be to make tests to verify our choice. In other words to isolate the faulty circuit group. Usually it is more convenient to make checks at a major test point than to make connections direct to the circuit. In this case, test point B is not directly connected to the output of the i-f amplifier group because CR4 is at the input; however, it would be a logical place to check to isolate the video group. Actually there are only a few components left in the video group that have not already been eliminated. A check at test point B should isolate the trouble to those remaining few components or trouble would be isolated to C21 or the MTI switch. If the output was faulty, the trouble would be isolated to the i-f amplifier group.

Assuming this check was made and the fault was found to be in the i-f amplifier group, where should the next check be made?

SELECTIONS:

A. Test point A.

B. Pin 1 of V101.

C. Pin 5 of V109.

A. Test point A.

Very good. If you selected this answer first, it is evident that you have correctly applied the principle of bracketing. The output of V109 is also the output of the suspected circuit group, but it is not a convenient test point. Test point A is the nearestcircled test point to the center of the trouble area.

B. Pin 1 of V101.

Definately not. It was previously stated that the input to all circuits was satisfactory, so nothing would be gained by checking at this point. The next check should attempt to isolate as many i-f circuits as possible. The half-split method could be used to divide the i-f groups; however, this would require a test at pin 1 of V105. The convenience of checking at test point A outweighs this decision and would be the best place to make the next check.

C. Pin 5 of V109.

No. Although this is the output of the suspected circuit group, the only component between this point and test point B is CR4. Remember you are attempting to eliminate as many circuits at one time as possible. A check here would provide little if any additional information not already determined by your previous check at test point B. Remember that access to test points was one of the considerations for moving brackets. No one rule should be rigidly adhered to if another one is more appropriate.

Ocassionally a test point will be shown on a servicing block diagram that appears to divide the circuit group in question, exactly in the center. Such is the case with test point G in figure 19, fold-out page 6.

Although this point appears to be the next logical test point, a test here may be misleading. This is because servicing block diagrams do not show coupling circuits between stages or circuit groups. There may be a large resistor between test point G and the grid of V104 which would greatly attenuate any signal coupled from V104 to the cathode of V504. Also filter circuits are often connected in coupling circuits to prevent signals from getting to the wrong circuit. Therefore, it should not be assumed that the i-f signal can be checked at test point G.

Assuming that there is no signal at test point A; the brackets would be moved to include V101 through V106.

Where should the next check be made?

SELECTIONS:

A. Test point G.

B. Pin 1 of V104.

A. Test poing G.

Definitely not. You evidently did not follow the last block of information very close. It was pointed out that servicing block diagrams do not show coupling circuits between stages or circuit groups. There may be some component between V104 and V105 that would attenuate the signal and lead to a false indication.

B. Pin 1 of V104.

Yes. This is a good choice for use with half-split method. There may be coupling circuits between test point G and the grid of V104; therefore, the check should be made at the main signal path. Resistors and filters are often employed in coupling circuits to prevent signals form getting into the wrong circuit. If the STC circuits had been a main signal path, and had not been eliminated by operating the STC switch, test poing G would have been a logical selection, since it is the output of a convergent signal path. In this example, assume that a satisfactory signal is found at the grid of V104. The brackets will now enclose V104, V105, and V106.

The next test point is a tossup between the input of V105 and the input of V106. Since the i-f signals are very weak in the first i-f amplifiers, it will probably be easier to make the test at pin 1 of V106. Assume in this example that a test reveals no signal at this point. The brackets are now enclosing only V104 and V105.

Now assume that a test at the input to V105 reveals a satisfactory signal. V105 can be bracketed, and step 5--localizing trouble to the circuit--has been completed.

SUMMARY

From the discussion of bracketing procedures and applications presented in this lesson, it should now be apparent that the procedure to be used is dependent upon the signal paths and circuit arrangement involved in the equipment being analyzed. It should also be apparent that, in general, two or three--or even all--of the bracketing techniques may have to be used in combination, since most equipments are complex enough to contain several circuit arrangements.

The over-all procedure to be used in step 5, however, should always follow a certain pattern. Before the narrowing down process begins, you should analyze the information previously obtained and determine whether you have sufficient data to begin the bracketing procedure.

Brackets are originally placed at the correct input(s) and incorrect output(s) of the faulty functional section, and the input-conversion-output analogy is applied to determine whether the symptoms point to one or more circuit groups in particular.

The sub-functions performed by the various circuit groups and the signal paths interconnecting these groups should be considered in this selection of possible faulty circuit groups. The inputs and/or outputs of these circuit groups should be checked, the most probable faulty sub-functions being checked first.

The accessibility of test points is an important consideration when checking these circuit groups. As each test is performed, an input bracket is moved to this point if the signal is satisfactory, and an output or closing bracket if the signal is unsatisfactory.

When the brackets enclose a signal circuit group, the input-conversion-output analogy and the signal paths within the circuit groups are considered to determine where to make the next test. Each test should attempt to eliminate as many circuits from the bracketed area as possible, unless the symptoms indicate that one or more circuits are more likely to be at fault than the rest of the circuit group. This process is continued until the brackets are at the input and output of a signal circuit.

The servicing block diagram is an invaluable aid in each step of the bracketing procedure. It provides you with a pictorial guide which indicates the main and secondary signal paths, shows the waveforms to be expected at important test points, and divides the function into circuit groups with titles to indicate their sub-functions.

In step 6 failure analysis, which is in the next lesson, you will learn how to continue the troubleshooting procedure to locate the faulty part in the circuit isolated in step 5.

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STEP 6. FAILURE ANALYSIS

The recognition, verifications, and descriptive information obtained in steps 1 and 2--symptom recognition and symptom elaboration--enabled you to make a logical and valid estimate concerning the selection of the faulty functional unit in step 3. In step 4--localizing the faulty function--you performed the simple input-output tests on the proper fault. Step 5 carried you deeper into the circuits comprising the equipment being tested. This step--localizing trouble to the circuit--required that you perform extensive tests as prescribed by the bracketing procedure suited for the particular circuit arrangement involved. This bracketing procedure enabled you to find the malfunctioning circuit or stage within the faulty functional unit.

The final step in our six-step troubleshooting procedure--failure analysis--will require that you test certain branches of the faulty circuit in order to determine where the faulty part lies. These branches are the interconnected networds associated with each element of the vacuum tube, transistor, or other active device in the faulty circuit. A more detailed discussion of these branches is incorporated in subsequent sections of this lesson.

Step 6--failure analysis--places you in the position necessary to replace or repair faulty circuit components so that the equipment can be returned to optimum serviceability. However, locating the faulty part does not complete step 6. You will also be concerned with determining the cause of the failure. It is quite possible that still another failure occurred and, unless all faults are corrected, the trouble will reoccur at a later date. The final step in failure analysis requires that certain records be maintained. These records will aid you or some other electronics technician in the future. They may also point out consistent failures which could be caused by a design error. When this step has been finished satisfactorily you can perform whatever repairs are necessary.

Which of the selections below best describes step 6--failure analysis--of our six-step troubleshooting procedure?

SELECTIONS:

A. This step permits you to repair the faulty parts in the circuit previously isolated by a bracketing procedure.

B. This step is designed to help you locate and verify all faulty parts in the set being tested.

C. This step permits you to correct the underlying fault before the faulty part is repaired.

A. This step permits you to repair the faulty parts in the circuit previously isolated by a bracketing procedure.

No. Repairing faulty parts is not actually a step in our six-step trouble-shooting procedure. Repair techniques are separate since our trouble-shooting procedure is concerned with locating the parts which must be repaired. By successfully completing this step, we will have located not only the faulty parts in the previously isolated circuit, but also other parts which may not have produced symptoms of malfunction during the previous tests. For example, an open cathode resistor in an amplifier circuit could have been caused by a shorted vacuum tube. Unless the vacuum tube, as well as the resistor, is replaced, the new resistor will burn out as soon as the amplifier goes into operation. Other examples will be developed as we proceed with this lesson.

B. This step is designed to help you locate and verify all faulty parts in the set being tested.

Yes. A faulty part in one branch of a circuit could be caused by a faulty part in another branch or even in another circuit. This fault may be of such a nature that it did not make itself apparent during previous tests. The successful completion of this step will have located and verified all faults in the equipment. Such success ensures that you have done an effective job and that you will not be called upon to repair the set in a day or two with the same trouble symptom.

C. This step permits you to correct the underlying fault before the faulty part is repaired.

No. The underlying fault may not be evident until all tests have been completed and the faulty component isolated. At this time you must ask yourself "would this faulty part result in other faulty parts, or is this a result of another fault". This will be discussed further as we proceed with the lesson.

Schematic Diagrams

Schematic diagrams illustrate the detailed circuit arrangements of electronic parts (represented symbolically) which make up the complete circuits within the equipment or unit. These diagrams show what is inside the blocks on a servicing block diagram and provide the final picture of an electronic equipment.

Figure 30, fold-out page 11, shows the schematic diagram of the receiver unit for a transceiver set. The receiver unit differs slightly

from the one illustrated by the servicing block diagram in figure 14, fold-out page 4. The frequency conversion function is accomplished in a single tube--there are no separate mixer and r-f oscillator circuits. Only one i-f amplifier circuit is used.

Note that the values of the circuit parts are listed. Each part is also given a reference designation for identification purposes. These diagrams will be very helpful in making tests not shown directly on the servicing block diagram, as well as determining which branch of an isolated faulty circuit needs to be repaired. For example, to check the bias resistor of the phase splitter tube, V6, you could place the multimeter probes on pin 7 and the junction of R19 and R21. The value, as shown, should be 1000 ohms.

To check your ability to use the schematic diagram select the correct answer to the following question: At what tube connections could you check the continuity of the entire primary circuit for the output transformer (T6)?

SELECTIONS:

A. Pin 6 of V7 and pin 5 of V8.

B. Pin 6 of both tubes, V7 and V8.

C. Pin 5 of both tubes, V7 and V8.

A. Pin 6 of V7 and pin 5 of V8.

No. This would test the continuity of only one half of the transformer primary. The question asked for a continuity check of the entire primary circuit. Restudy the diagram on fold-out page 11 and choose the test points that will measure the continuity of the entire transformer.

B. Pin 6 of both tubes, V7 and V8.

Absolutely not. Pin 6 for both tubes is a common point from an electrical standpoint. Placing the test instrument across these two connections would merely test the continuity of the lead between the screen grids of the two tubes.

C. Pin 5 of both tubes, V7 and V8.

Right. Connecting the test instrument to these points would place it across the entire primary circuit.

Voltage and Resistance Charts

Once the faulty circuit has been isolated, the voltages and resistances of the various circuit branches must be measured, in order to determine which components within the circuit are at fault. The measurement results must be compared to voltage and resistance charts or tables in order to evaluate them. This information may appear on the apron of its associated fold-out schematic diagram, or it may be on a separate page(s) in the manual. The normal voltage and resistance reading to ground (or other point of significance) for each tube socket pin is given. Also listed are the conditions necessary to observe the gain reading, such as control settings and equipment connections.

An example of a tube voltage and resistance chart is given in figure 17, fold-out pages 49, 50, of the Instruction Book for Oscilloscope TS-O, Vol 3 of this course. The tabular form provides the same information without using the tube socket diagrams.

To see the use of these charts, refer to figure 17 of the TS-O manual. If the first vertical d-c amplifier circuit (tube V102) of the TS-O was found to be the cause of a "no vertical deflection" trouble symptom, we would measure the voltages and resistances at the various pin connections of V102. According to the servicing block diagram, figure 19, fold-out pages 53, 54, the pins most important to proper signal flow are numbers 2 and 1, of tube V102A and pins 6 and 7 of tube V102B, Pin 8 (not shown) is part of V102B and also effects the signal flow. According

to the voltage and resistance chart on figure 17, fold out pages 49, 50, the voltages at pins 1 and 2 should be 95 volts and zero volts, respectively. The grid (pin 2) voltage is zero because there should be no input signal during this test, as stated in the notes of figure 17 on fold-out pages 49, 50. The respective resistance should be 50 K and zero ohms. The voltages for pins 6, 7, and 8 should be 95, -0.1, and 0.4 volts, respectively, and the resistance should be 50 K, 3.3 K, and 100 ohms. If these primary branches check out satisfactorily, the voltages and resistances at the remaining pins (3, 4, 5, and 9) should be checked. The readings at these pins should be 1.2, 3.15 (ac) 3.15 (ac), and 3.15 (ac) volts and 390 ohms, zero ohms, zero ohms, and zero ohms, respectively. A-C voltages are present at pins 4 and 5 because these pins are the heater connections.

Remember that an infinite resistance reading indicates an open circuit, and that a zero reading indicates a direct short to ground (or to whatever reference point is designated by the resistance chart). A more detailed discussion of the application and interpretation of these tests will be given later in this lesson.

Using the same charts as mentioned in the example above, what should be the resistance of the synchronization amplifier at the input connection?

SELECTIONS:

A. 1 megohm.

B. 3.3K.

C. 125K.

A. 1 megohm.

Good. According to the servicing block diagram (fold-out page 53, 54 of the TS-O Manual) the input to the synchronization amplifier is provided at G7--the grid, pin 7 of V101B. The voltage and resistance chart on fold-out pages 49, 50 of the TS-O manual lists a resistance of 1 megohm from pin 7 of V101 to ground. A zero resistance reading at the grid of this tube would be an indication of a shorted grid circuit. This condition would prevent the synchronization signal from being amplified and coupled to the sweep circuit oscillator. There would be an unstable display on the cathode-ray screen, and the locking control would have no effect. An infinite resistance reading at this point would be an indication of an open grid resistor. The effect of an open grid resistor is not always predictable. It would depend upon the type of tube and the amplitude of the input signal. However, in most cases the result would be similar to that of a shorted grid circuit; that is, the locking control would be ineffective.

B. 3.3K.

Wrong. The resistance at the cathode, pin 3 of V101B, is in the output circuit and provides an output in phase with the grid.

C. 125K.

No. This is the resistance at pin 6, the plate of V101B. The plate circuit is tapped to provide the synchronization amplifier output signal, not the input signal.

TYPES OF CIRCUIT TROUBLE

In Lesson No. 1, we recognized that an equipment was not functioning from the audible and visual indications of performance. Equipment failure results in a complete lack of performance information which would normally be seen or heard by the equipment operator. The second type of abnormal performance we discussed was "degraded performance." For this type the visual and audible indications are present, but they are not up to the specifications provided for normal operation.

Regardless of the type of trouble symptom, the actual fault can eventually be traced to one or more of the circuit parts--resistors, capacitors, etc--within the equipment. The actual fault may also be classified by the degree of malfunction. The complete failure or abnormal performance of a part, of course, falls in line with the previous use of these terms. These types of faults are easily discovered.

There is a third degree of part malfunction which is not always so obvious. This is the intermittent part malfunction. Intermittent, by

definition, refers to something which alternately ceases and begins again. This same definition applies to electronic part malfunctions. The part operates normally for a period of time, then fails completely or operates on a degraded level for a while, and then returns to normal operation. The cyclic nature of this malfunction is an aid in determining that it exists. However, it is often difficult, to locate the actual faulty part. This is true because of the fact that while you are testing the circuit in which this part lies, it may be operating normally. Thus you will pass it by as satisfactory, only to be faced with trouble again as soon as the cycle of operation completes itself.

An example of intermittent trouble would be cyclic appearance and disappearance of the return trace on the screen of the TS-O oscilloscope. From previous discussions and by studying the servicing block diagram on fold-out pages 53, 54 of the TS-O manual, you can see that the intensity modulation amplifier (V105B) it directly responsible for producing the "blanking signal," which normally attenuates the return trace to such a degree that it is not visible on the screen. This blanking signal comes from the plate, pin 6, of V105B. Normally, this pin is connected to a load resistor, across which the blanking voltage is developed.

Now suppose that, as current flows, the heat developed causes the connection at pin 6 to expand and lose contact with the load resistor. When this occurs, the voltage across the load is lost, and the return trace is not blanked. When contact is lost, current ceases. Thus, the connection has a chance to cool and make contact again. As soon as this occurs, current again flows, the voltage is reapplied across the load, and the return trace disappears. This cycle from normal operation and back to normal again continues as long as the oscilloscope is operated with the intermittent trouble present.

Which of the three degrees of malfunction is the most difficult to isolate?

SELECTIONS:

A. Complete part failure.

B. Degraded part performance.

C. Intermittent part malfunction.

A. Complete part failure.

No. This is probably the easiest of the three degrees of malfunction to detect, because the trouble would always exist and would show up when tests were made.

B. Degraded part performance.

No. The degraded performance is continuous and will show up while you are evaluating the performance of the circuit in which the part is located.

C. Intermittent part malfunction.

Yes. Since the part may be operating normally while you are testing the particular circuit in which it is located, you can easily pass over the circuit during trouble isolation tests. However, the cyclic nature of the intermittent type of malfunction should tip you off and make you regard the test results suspiciously. Although it will consume more time than usual, you must perform your tests only while the failure is occurring. If the cycle of operation is rapid enough, however, the usual tests can be performed, and the faulty part can be discovered just as quickly as if it were malfunctioning continuously.

ISOLATION OF FAULTY PARTS.

The first step in isolating a faulty part within a circuit is to apply the same input-conversion-output method used in previous steps. The output signal should be analyzed to aid in making a valid of the parts or branch of the circuit which may cause the defective output. The voltage, duration, and/or shape of the output waveform may be indications of possible open or shorted parts or out-of-tolerance values. This step performs two functions: it reduces to a minimum the number of test readings required, and it helps determine whether the faulty part, when located, is the sole cause of the malfunction.

The second step in isolating a faulty part is a visual inspection of the parts and leads in the circuit. Often this inspection will reveal burned or broken parts or defective connections. Open filaments in vacuum tubes may also be spotted in this check.

Voltage measurements at the pins of vacuum tubes or at transistor leads can be compared with the normal voltages listed in available voltage charts to provide valuable aid in locating the trouble. This check will often help isolate the trouble to a single branch of a circuit. A separate

circuit branch is generally associated with each pin connection of the vacuum tube or transistor.

Resistance checks at the same points are also useful in locating the trouble. Suspected parts can often be checked by a resistance measurement.

When a part is suspected of being defective, a good part may be substituted for it in the circuit. You must keep in mind, however, than an undetermined fault in the circuit may also damage the substituted part. Another factor to consider before performing this step is that some circuits are critical and substituting parts (especially vacuum tubes or transistors) may alter the circuit parameters.

In some equipments the circuits are specifically designed for the substitution process. For example, the plug-in circuit module is being employed in many new electronic equipments. It contains all of the necessary parts (resistors, capacitors, and inductors) for a circuit branch or even the entire circuit. Once a trouble has been bracketed to a module, substitution of the module is the only method of correcting the fault.

Five steps have been suggested to be employed in isolating a trouble to a faulty part. The first step is to apply the input-conversion-output method of analyzing the output of the faulty circuit. Assuming that the circuit contains no plug-in modules, which of the following selections gives the correct order for the other four steps?

SUGGESTIONS:

A. Visual inspection, voltage measurements, resistance measurements, and parts substitution.

B. Visual inspection, parts substitution, voltage measurements, and resistance measurements.

C. Visual inspection, resistance measurements, voltage measurements, and parts substitution.

A. Visual inspection, voltage measurements, resistance measurements, and parts substitution.

Yes. This sequence follows the fundamental logic we have advocated--systematically "narrowing down" the trouble area until the faulty part is found. Visual inspection, voltage measurements, and resistance measurements will isolate the trouble to a circuit branch--a logical step below the circuit level. Voltage measurements are made with the circuit in operation, but with no signal applied. Resistance measurements are performed with no power applied to the equipment. Active tests are always preferred to inactive tests, as was pointed out in the lesson on bracketing techniques. Once the faulty circuit branch is isolated, we can find the actual part at fault. Here parts substitution may be an aid.

B. Visual inspection, parts substitution, voltage measurements, and resistance measurements.

No. What fundamental logic have we followed throughout our studies? We have always proceeded from a large trouble area to a smaller trouble area in a systematic manner. Thus, we reduced the locality of the fault from an equipment to a functional unit, then to a circuit group, and finally to a circuit. The selection you have made places parts substitution before voltage measurements; therefore, you would be trying to isolate a faulty component before you know which circuit branch contains the trouble.

C. Visual inspection, parts substitution, resistance measurements, and voltage measurements.

Absolutely not. What fundamental logic have we followed throughout our studies? We have always proceeded from a large trouble area to a smaller trouble area in a systematic manner. Thus, we reduced the locality of the fault from an equipment to a functional unit, then to a circuit group, and finally to a circuit. The selection you have made places parts substitution before voltage measurements; therefore, you would be trying to isolate a faulty part before you know which circuit branch contains the trouble. Voltage measurements are performed prior to resistance measurements since they can be conducted on active circuits (energized equipment). Indications of faulty voltage measurements leads to the components or branches for resistance checks.

Systematic Checks

Probable deductions should always be checked first. Next, because of the safety prectice of setting a voltmeter to its highest scale before making measurements, the points having the highest voltages--plates and screen grids--should be checked. Then the elements having smaller voltages should be checked in the descending order of their applied voltage, that is, the cathode and then the control grid. This also applies to transistors; thus, the collector is normally checked first and then the emitter and base.

Voltage, resistance, and waveform readings are seldom identical to those listed in the manual. The most important question concerning voltage checks is, "How close is good enough?" In answering this question, there are many factors to consider. The tolerances of the resistors, which greatly affect the voltage readings in a circuit, may be 20 %, 10%, or 5%; in some critical circuits, precision parts are used. The tolerances marked or color-coded on the parts are therefore one important factor. Vacuum tubes and transistors have a fairly wide range of characteristics and will thus cause variations in voltage readings. The accuracy of the test instruments must also be considered. Most voltmeters have accuracies of 5 to 10 percent, while precision meters are more accurate.

For proper operation, critical circuits may require voltage readings within 10 percent of the values specified in the manual; however, most circuits will operate satisfactorily if the voltages are 20 to 30 percent off. Important factors to consider are the symptoms and the output signal. If not output signal is produced at all, you should expect a fairly large variation of voltages in the trouble area. A trouble which results in a circuit performance just out of tolerance, however, may cause only a slight change in circuit voltages.

Consulting the schematic, figure 30, fold-out page 11, which selection below gives the proper sequence for performing a voltage check of the circuit branches in the r-f amplifier?

SELECTIONS:

A. 5, 1, 7, and 6.

B. 5, 2, 6, 7, and 1.

C. 5, 6, 7, and 1.

A. Pins 5, 1, 7, and 6.

No. This selection violates the sequence specified in the information section. The pin sequence for this selection, in terms of tube elements, is plate, control gird, cathode, and screen grid. If measurements were made in this sequence, it is possible that test equipment could be damaged if the scale was not changed each time.

B. Pins 5, 2, 6, 7, and 1.

No. The sequence is wrong. Previous information stated that the high voltage pins should be checked first and then the lesser voltage pins should be checked in the order of their decending voltage. This is a safety precaution that should be followed to prevent damage to the test equipment by neglecting to change to the proper scale.

There would be no reason for checking pin 2 since is is directly connected to the cathode, pin 7.

C. Pins 5, 6, 7, and 1.

Yes. This follows the sequence--plate, screen grid, cathode, and control grid--given in the information section.

This sequence will prevent damage to the test equipment if the range scale is not rotated since the higher voltages are measured first.

Locating the faulty part

The voltage and/or resistance checks discussed previously indicate which branch within a circuit is at fault. We must now isolate the trouble to a particular par (or parts) within the branch.

One procedure for accomplishing this is to move the test probe to the different points where two or more parts are joined together electrically and measure the voltage or resistance with respect to ground. Generally, however, the correct values (particularly voltage) will be difficult to determine from these points on a schematic diagram and may not be available elsewhere. Thus, we shall reserve this procedure for making resistance checks to locate shorts and openings in the branch.

A better check to use when voltage readings are not normal is a systematic check of the value of each resistor, capacitor, and/or inductor in the branch. The instruments required for these measurements include impedance bridges, Q-meters, etc.

Referring to the schematic diagram in figure 30, fold-out page 11, assume that the power supply is connected and contains a bleeder resistor to ground that is known to be good. A resistance check between pin 6 of the i-f amplifier (V3) and ground gives an infinite reading. However, a close visual inspection shows that there is no open circuit at the pin connection itself. In what path must an open exist?

SELECTIONS:

A. The path between pin 6 and the grounded side of C18.

B. The path through R11 and R12.

C. The path through R11 and C21.

A. The path between pin 6 and the grounded side of C18.

Absolutely not. Resistance measurements, remember, are made with no primary power applied to the electronic equipment. The necessary d-c voltage is provided by the test instrument. The resulting direct current follows the path of least resistance between the test probe and the common connection. Except for a momentary charging current, a capacitor does not permit direct current flow--it is normally an open circuit to such flow. Therefore, the open circuit must lie in another path to ground.

B. The path through R11 and R12.

Yes. Here we must utilize test equipment knowledge fundamental electronics knowledge, and the ability to interpret schematic diagrams. The instrument used to measure resistance supplies its own direct voltage (and, therefore, direct current) to the parts being tested. No primary power is applied to the equipment under test.

Current follows the path of least resistance. A capacitor presents an infinite resistance to dc. Thus, if a test instrument is connected between pin 6 of the i-f amplifier (fold-out page 11) and ground, the normal current path is from pin 6 through R11 and R12.

Normally, the reading from pin 6 to ground through R11 and R12 should be 25K plus the resistance of the power-supply bleeder. Therefore, an infinite reading indicates an open in the path through R11 and R12.

C. The path through R11 and C21.

Absolutely not. Resistance measurements, remember, are made with no primary power applied to the electronic equipment. The necessary d-c direct voltage is provided by the path of least resistance between the test probe and the common connection. Except for a momentary charging current, a capacitor does not permit direct current flow--it is normally an open circuit to such flow. Therefore, the open circuit must lie in another path to ground.

REVIEW OF PREVIOUS DATA

A review of all the symptom and test information obtained thus far will help isolate other faulty parts, whether the malfunction of these parts is due to the isolated malfunction or to some entirely unrelated cause.

In order to achieve this indication of multiple malfunction, we will start with the part we have isolated and ask the question, "What effect does the malfunction of this part have on the operational function of the equipment?" If the isolated malfunction can produce all of the normal and abnormal symptoms and indications we have accumulated, we can logically assume that it is the sole item at fault. If not, we must utilize our knowledge of electronics and of the equipment itself to determine what other malfunction(s) must also occur to provide all of the symptoms and test data.

Referring to the schematic, figure 18, fold-out pages 51, 52 of the TS-O manual, assume that our troubleshooting procedure has isolated the trouble to the vertical positioning control, R111, in the cathode circuit of V102B. This faulty resistor was discovered because the bias voltage on the grid of V102B was not at its normal value. What trouble symptom and associated information would this produce?

SELECTIONS:

A. The vertical positioning of the CRT trace will be effected when low frequency signals are applied to V102.

B. The vertical positioning of the CRT trace will be effected when high frequency signals are applied to V102.

A. The vertical positioning of the CRT trace will be effected when low frequency signals are applied to V102.

No. When low frequency signals are applied to V102, only the A section will amplify the signal. The impedance of C109 prevents low frequency signals from being coupled to V102B.

B. The vertical positioning of the CRT trace will be effected when high frequency signals are applied to V102.

Yes. When high frequency signals are amplified by V102A, a portion of the signal is fed to V102B via C109. This is turn is amplified by V102B and fed to the 2nd d-c amplifier, V104.

Paragraph (3), on page 22 of the TS-O manual, gives a complete description of the operation of the first vertical d-c amplifier (V102B). By studying this information, you will discover that R111 controls the bias on V102B which, in turn, affects the vertical position of the display on the cathode-ray tube. Since this is the only function of R111, we would expect a lack of vertical positioning of the display to be the sole trouble symptom.

Let's assume that, in addition to a lack of vertical positioning, there is also very poor vertical amplitude response at high input frequencies. A faulty potentiometer (R111) could not cause this symptom; therefore, we must locate another source of malfunction.

Let's assume also that during our testing which isolated R111 we found that the amplitude of the output from V103 and V104, as well as the input to these tubes, was below normal at high frequencies and satisfactory at lower frequencies. However, the input to V102A was satisfactory. Remember, these were the bracketing tests which led us to the first vertical d-c amplifier as the source of the trouble. A voltage check at the grid of V102B showed an abnormal bias, and a further check of the grid circuit isolated R111 as being at fault. Now we know that some other part in the first vertical d-c amplifier circuit must also be at fault. This fault must be responsible for satisfactory operation at low frequencies and abnormal (loss of signal amplitude) at high frequencies.

It is essential to check the tube (V102) since a faulty tube could produce the same symptom. If the elements associated with the V102B function were faulty while those associated with V102A were not, the latter portion would carry low-frequency signals in a normal manner. However,

because of the fault in the V102B elements, the high-frequency signals would not be given the additional amplification provided by the normal push-pull action of the V102 combination.

The information is paragraph (3b) on page 23 of the TS-O manual indicates one part which could provide this symptom--the grid of V102B. Thus, we should check this part as the third possible malfunction.

Suppose you have isolated a trouble to a part and then discover that a failure of this part would not result in all of the symptoms and irregularities in your test data. Which of the following conclusions is most appropriate at this point?

SELECTIONS:

A. I have not isolated the faulty part.

B. There is another defective part.

C. I have not correctly interpreted the symptoms.

A. I have not isolated the faulty part.

Wrong. Your tests have indicated that this part is faulty. You should recall the previous information and look for another fault. One faulty component may have resulted in another fault. You should not conclude that this could not be the faulty part just because it does not fit all of the symptoms.

B. There is another defective part.

Correct. When one part fails, it often results in abnormal voltages or currents which cause damage to other parts. Often a trouble is isolated to a faulty part which is a result of the original trouble rather than its source.

C. I have not correctly interpreted the symptoms.

Wrong. The fact that the suspected faulty part could not cause all of the symptoms is not sufficient reason to believe that the symptoms have not been interpreted correctly. It is quite possible that one faulty component may result in another fault. Additional checks should bear this out.

Common Malfunction Causes

The review of accumulated test information as discussed in the preceding section is indispensable to the recognition and isolation of multiple malfunction or directly caused by the isolated malfunction. How about the isolated malfunction itself? What could have caused the trouble?

Consider the transistor amplifier circuit shown in figure 31. Assume that our troubleshooting procedures have isolated the transistor as the cause of trouble--it is burned out. What could cause this? Excessive current can destroy the transistor by causing internal shorts or by altering the characteristics of the semiconductor material, which may be very temperature-sensitive. Thus, the problem reduces to a matter of determining how excessive current can be produced.

Excessive current could be caused by an excessively large input signal, which would overdrive the transistor. Such an occurance would indicate a fault somewhere in the circuitry preceding the input connection.

Power surges (intermittent excessive outputs) from the power supply could also cause the burn-out. In fact, power supply surges are a common cause of transistor (and vacuum-tube) burn-out.

It is advisable to check for the conditions just mentioned before placing a new transistor in the circuit. Bias stabilization circuits are generally included (as in figure 31) to lesson the effect of excessive bias currents.

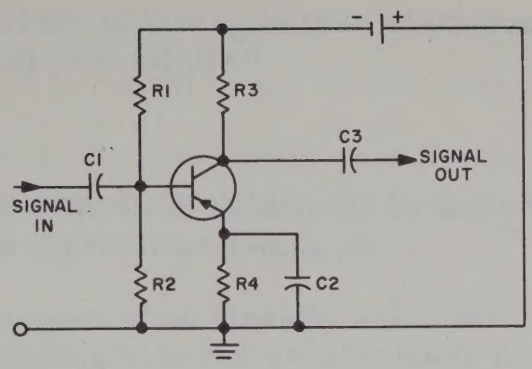

Figure 31. Transistor Amplifier Circuit

Some other malfunctions, along with their common causes, include:

1. Burned-out cathode resistors caused by shorts in vacuum-tube elements.
2. Power supply overload caused by a short-circuit in some portion of the voltage distribution network.
3. Burned-out transformer in shunt feed system caused by shorted blocking capacitor.
4. Burned-out fuses caused by power-supply surges or shorts in filtering (power) networks.

In general, a degraded component characteristic can be traced to an operating condition which caused the maximum ratings of the component to be exceeded. The condition may be temporary and accidental, or it may be deeply rooted in the circuitry itself.

Bad tubes account for over 60 percent of all equipment malfunctions. For this reason, the possibility of such a fault should be uppermost in your mind when you have reached this point in our six-step trouble-shooting procedure.

As tubes age they undergo certain inherent changes. For example, there is a change in transconductance which generally lowers the gain of the tube. Also, the heater-to-cathode leakage current increases with age. This current is responsible for hum and other undesirable "coupling" effects between the heater and cathode. The period of time required for the leakage increase is shortened if the tube is frequently operated at a higher-than-normal temperature.

Other tube troubles include grid current variations, gas leakage (in a vacuum tube), and improper usage (operation at excessive values).

A consideration of these factors can locate multiple malfunctions, as well as prevent a future failure of similar nature.

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In general, which of the following is true of the causes of abnormal circuit operation and part failure?

SELECTIONS:

A. The causes are difficult to determine because they are not directly associated with the malfunctioning part.

B. The causes are most often directly associated with the operation of the malfunctioning part and usually takes the form of excessive voltages or currents.

A. The causes are difficult to determine because they are not directly associated with the malfunctioning part.

Absolutely wrong. You evidently misunderstood the previous information. The cause is directly associated with the operation, function, and circuitry of the malfunctioning part. You must stop and analyze the failure to determine what could have caused the failure and if the faulty part could cause another fault.

B. The causes are most often directly associated with the operation of the malfunctioning part and usually takes the form of excessive voltages or currents.

Yes. Abnormal performance and failure of a part can generally be traced to a temporary or continuous excess of voltage or current. For this excess to cause damage, there must be a continuous connection between the original malfunctioning part and the true source of trouble.

Of course, there are other causes of trouble also. These include mishandling of equipment, normal aging of parts, and hostile environment (moisture, radiation, cold, etc).

FAILURE REPORTS

A Failure Report must be filled out for the failure of any part of the equipment, whether caused by defective or worn parts, improper operation, or external influences.

Failure report forms may differ depending on who has cognizance of the equipment, i.e., electronic equipment-Bushipsi; ordnance electronic equipment-BuWeps. The technician should refer to the proper Electronic Maintenance and Installation Book (EIMB), NavShips 0967-000 series to determine the proper form to be used. If the electronic equipment is under cognizance of BuWeps, current instructions be consulted to determine the proper form to be used.

BuShip failure report forms give full instructions on each pad. In filing the card out, make certain that the information given is correct and adequate. Under REFERENCE DESIGNATION use the proper part identification from the schematic drawings, such as T105 in the case of a transformer or R203 for a resistor. Do not substitute brevity for clarity. Use the back of the card to completely describe the cause of failure; if more space is necessary, attach a piece of paper to the card.

The purpose of this report is to inform BUSHIPS of the cause and rate of failures. The information is used by BUSHIPS in the design of future equipment and the maintenance of adequate supplies to keep the present equipment going. The cards you send in, together with those from hundreds of other ships, furnish a store of information which permits the Bureau to keep in touch with the performance of the equipment on your ship, and all other ships of the Navy.

The Failure Report has a personal side, too. It shows that you are doing your job, it may help make the job easier for you in the future, it helps you pass your knowledge and experience to every other electronics man, and it prepares you for the next higher rating.

Is a troubleshooting project complete without submitting a Failure Report?

SELECTIONS:

A. Yes, because the failure report is not part of the troubleshooting procedure.

B. No. The failure report form is part of the troubleshooting procedure.

C. The failure report form can be sumbitted anytime.

A. Yes, because the failure report is not part of the troubleshooting procedure.

Wrong. Only after the form is submitted have you completed your project. You can find the trouble, make the necessary repairs, and return the equipment to service, but until you file a failure report your job is not finished.

B. No. The failure report form is part of the troubleshooting procedure.

Right. No matter how good a job you do, it isn't finished until after you file the failure report.

C. The failure report form can be sumbitted anytime.

Definitely not. Only through prompt submission of the failure report form can an analysis be made to determine what changes are necessary in order to improve the equipment. Failure report forms should be completed and submitted as soon as the faulty part is replaced.

This final step--Failure Analysis--has brought you to the end of our six-step troubleshooting procedure. You have "narrowed down" the trouble area with each successive step until the malfunctioning part has been isolated. You have reviewed your procedure to ensure that multiple malfunctions do not exist and to verify the cause of the malfunction. You have also made the necessary records of your actions.

By replacing the faulty part and re-checking equipment operation, you can return the equipment to the operator with the knowledge that you have completed your troubleshooting duties.

Although not directly connected with troubleshooting procedures previously outlined, the technician should reorder any parts used in the repair of the faulty equipment. Proper logistic support will enable the technician to return the equipment to an operating status once the trouble has been located.

You have studied the six steps of the troubleshooting procedure. Next you will be given problems which will require you to utilize this information to locate troubles by theoretical troubleshooting. Go to Volume 2 and commence the problem lessons.

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